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ORIGINAL ARTICLES.

I.—Lamarck and Playfair: A Geological Retrospect of the Year 1802.[1]

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(*Concluded from the April Number, p.* 153.)

If Lamarck allowed his brilliant faculty of generalisation to lead him far astray in his opinions regarding the origin of rocks, he had formed a saner judgment on the causes that have developed the present terrestrial topography. The first chapter of the "Hydrogéologie" is devoted to a consideration of the natural results that arise from the circulation of water over the surface of the land. This subject, he remarks, affords less scope than any other for the exercise of the imagination in framing hypotheses, for it can be studied on a basis of facts which are generally familiar. Though the question required to be considered in his treatise and was capable of easy solution, yet it seemed to him to be novel, at least from a general point of view, and to have been previously neglected by physicists and naturalists. He appears to have formed his conclusions regarding it independently, and to have been unaware how far he had been anticipated by previous observers. It is singular that he makes no allusion to the work of his distinguished fellow-countryman Desmarest, who some thirty years previously had demonstrated, from a prolonged and minute investigation of the volcanic history of Auvergne, that the valleys of that region have been excavated by the streams which flow in them. He does not refer to the enunciation of the same doctrine by De Saussure a few years later in regard to the valleys of the Alps, nor to the clear presentation of similar views by Hutton, whose system had been expounded to French readers by Desmarest. But though he was mistaken in supposing that the doctrine was novel, Lamarck was not surpassed by any of his predecessors in the firmness with which he espoused it, and in the clearness with which he presented it to the world. Realising so fully as he did the magnitude of the scale

[1] An address delivered before the "Alliance Française" in the Sorbonne, Paris, on 26th February, 1906.

on which the surface of the land undergoes disintegration, he could see no difficulty in conceiving that the mere passage of running water over that surface must inevitably lead to the erosion of a system of drainage-lines from the mountain-crests down to the margin of the sea. In language closely similar to that employed at the same time by Playfair in the volume which appeared at Edinburgh, he remarks:—"If we suppose the exposed part of the surface of the earth to have been originally a vast plain, unvaried either by mountains or valleys, and having no other curvature than that of the general form of the globe, though such a supposition is not necessary, seeing that the lands successively abandoned by the ocean in its westerly movement would not all be without irregularities in their surface, I can easily show that at the end of a certain period of time the influence of the subaerial waters will have modified or destroyed the regularity of surface of this plain, and will ultimately form mountains like those which are familiar to us" (pp. 11, 12). "This sequence of events is that followed by Nature in her known methods and processes which can be seen in progress every day before our eyes. It is thus evident to me that every mountain which is not the result of volcanic eruption or of some other local catastrophe has been cut out of a plain, and that its peaks and crests mark the relics of the ancient level of that plain" (p. 14).

That this interpretation holds true for the abundant hills and mountains composed of horizontal or little disturbed stratified formations is now an accepted conclusion of modern geology. But it will not explain the origin of the great mountain-chains of the earth's surface, which have been upheaved during the violent plication and rupture of the terrestrial crust. Of the real structure of such chains comparatively little was known in Lamarck's time, and even that little was not appreciated by him. He thought that the inclined arrangement of strata in many mountains was original, and might generally be taken to indicate the position of the shores on which the sediments were deposited, though it might in some cases be due to local disturbance. He knew that sometimes the strata in a mountain-chain are found to be vertical, but he would not on that account invoke for their explanation some universal catastrophe as had been advocated by other writers,[1] but contented himself with a vague reference to local subsidences (pp. 22, 23).

In his account of what he conceived to take place when the land is laid bare in consequence of the westward migration of the ocean, Lamarck involved himself in some curious contradictions. In the mental picture which he drew of the successive emergence of the marine deposits, including the granite ridges which had been laid down upon the sea-floor, he imagined that the surface of the plain, thus transformed into an area of land, was gradually heightened by the accumulation upon it of the remains of organisms, more especially

[1] He not improbably had Cuvier in his mind, who held this opinion and afterwards gave it prominence in his "Discours sur les Révolutions de la Surface du Globe," wherein he asserted that the occurrence of such a catastrophe, some 6,000 years ago, was one of the best ascertained facts in geology.

of vegetation. He thought that this organic deposit increased in thickness at the rate of one foot in a century, so that in no long course of time it must deeply bury the old sea-floor and even cover up the ridges of deposited granite. He did not show, however, by what means this general elevation of the surface of the plain could possibly be accomplished in face of the universal degradation caused by atmospheric decay and the circulation of water over the land—a destructive combination which he had already admitted that nothing can resist. Nor did he offer any explanation of the cause of the ultimate cessation of the upward growth of the organic deposit, or why after burying the granite ridges it eventually failed to keep pace with the erosive action of rain and rivers. Without noticing such obvious and serious objections to his theories, he could only contemplate the final result of the long process of earth-sculpture—the trenching of the terrestrial plain by running water, into gullies, gorges, and valleys, and at last the uncovering of the hard central cores of granite now to be seen in the heart of so many mountain-chains (pp. 149, 178).

It was when he left such speculations as these, for which no adequate basis of ascertained fact then existed, and turned his consummate genius to the patient study of the organic remains imbedded in the earth's crust, that Lamarck conferred the most valuable and imperishable benefits on the infant science of geology. The word 'fossil' had up to his time been indiscriminately applied to any substance dug out of the ground. Every mineral and rock was in this sense a fossil. But Lamarck, recognising the pre-eminent importance of organic remains as monuments of the history of the globe, first restricted the use of the word to them alone, and his example has since been everywhere followed. In the "Hydrogéologie" he pointed out that as fossil shells are nearly all of marine types their evidence could be used to demonstrate that the sea once covered the site of what is now land, and this by no mere transient and violent inundation, but tranquilly and for vast periods of time. As Lavoisier had done before him, he distinguished among them some that belonged to littoral or shallow-water species and others that were deep-sea or pelagic forms. He entered into a lengthened argument to disprove what had been for so many generations the orthodox belief that the shells found far inland and in the heart of mountains are memorials of Noah's Flood. Dwelling on the manner in which pelagic and littoral shells are found in separate beds, piled above each other, he insisted on the evidence thus furnished of successive quiet and long-continued deposition on the sea-bottom. He pointed to the significant occurrence of the two valves of bivalve shells still adhering to each other as proof that these organisms, instead of having been violently huddled together by some great catastrophe, had manifestly lived and died where their remains are now found. When he considered the abundance of marine organisms in our present seas and the vast amount of carbonate of lime secreted by them from the oceanic waters, he felt convinced that the masses of limestone which form so important

a part of the outer crust of the earth represent marine organic accumulations of former ages, although in course of time, by the operation of various causes, all trace of organised structures may have disappeared from them.

The "Hydrogéologie" was Lamarck's single treatise specially devoted to the discussion of geological problems, but it formed only the beginning of the labours by which he conferred the most signal benefits on geology and earned for himself the name of founder of invertebrate palæontology. For a long succession of years after the appearance of that volume in 1802 he gave much of his time and thought to the study of the fossil shells of the Paris Basin, and published the valuable series of memoirs on these organic remains which revealed the zoological riches of the Tertiary deposits of that region, and likewise served as an accurate basis for the detailed investigation of these deposits by Cuvier and Brongniart, who thereby did so much to lay the foundations of stratigraphical geology. These later achievements of the illustrious biologist, however, and his contributions to the theory of organic evolution lie beyond the scope of the present address. I have wished to direct attention to one of his less known works which, while it displays his weaknesses as well as his strength, is full of his philosophical genius and of that broad commanding view of all the wide domains of Nature which was so eminently characteristic of Lamarck.

From Paris and its busy laboratories and museums in which Lamarck quietly did his work, let us turn to Edinburgh, where at the same time a few thoughtful and enthusiastic men were discussing the same problems and were evolving some of the fundamental conceptions that have shaped the course of modern geology. James Hutton, the greatest genius in this northern group of philosophers, died in 1797, leaving behind him in published form only an incomplete account of his doctrines, but having impressed on the minds of his friends a profound admiration of the originality and grandeur of his conceptions of the history of our globe. It was fortunate for his fame, and not less so for the onward march of science, that one of these friends had gained so full and clear a knowledge of the master's teaching, and at the same time possessed such pre-eminent literary gifts, as to be able to present Hutton's doctrines in the remarkable volume to which I have now to ask your attention.

This loyal and accomplished friend, John Playfair, was born in 1748. The eldest son of a Scottish parish minister, he was educated for the Scottish Church at the University of St. Andrews. But during his college career he showed such high mathematical and philosophical attainments that, when only 18 years of age, he was encouraged by his professors to compete for the vacant Chair of Mathematics in the University of Aberdeen, and after a prolonged examination came out third in the list of candidates. Failing in this application, he eventually entered the Church, and was appointed to succeed his father in his Forfarshire parish. Amidst the quiet of

a remote country manse and in the duties of a parish minister he spent ten years of his life, supporting his mother and educating his younger brothers. But at the end of that time he resigned his living, and as his scientific tastes remained as strong as ever, he obtained in 1785 the appointment of Joint-Professor of Mathematics in the University of Edinburgh. His gentle and kindly nature, his high mental endowments, and his social charm soon gained for him an honoured place in the circle of philosophers, men of science, and of letters who at that time shed such lustre on the Scottish capital. Among the friendships which he specially cherished there was that of Hutton, who in the Spring of the same year (1785) read to the Royal Society of Edinburgh the first sketch of his famous "Theory of the Earth." Playfair's philosophic mind appears to have been early fascinated by the breadth and profundity of Hutton's views of Nature. As he used to accompany the geologist on his excursions in Scotland, and had abundant opportunities of listening to his enthusiastic disquisitions, Playfair enjoyed special facilities for gaining a fuller appreciation of Hutton's doctrine than could easily be gathered from the master's own writings, which, from their cumbrous and obscure style, had met with less recognition than their intrinsic originality and importance deserved. When, therefore, Hutton died, his admiring disciple determined to draw up a popular and perspicuous sketch of his friend's geological system. After working at the task for five years he published in the Spring of 1802 his well-known "Illustrations of the Huttonian Theory." Playfair's subsequent career was as uneventful as the years that had already passed. In 1805 he was transferred to the Chair of Natural Philosophy in Edinburgh University, an appointment which he continued to fill up to the end of his life. He contributed many articles and memoirs to the current literature of the day, and in his later years undertook many journeys at home and abroad in pursuit of geological studies. But an internal ailment brought his life to a close on 19th July, 1819, at the age of 71.

Playfair's loyalty to his great teacher, and his earnest desire to set the Huttonian system in a clear and attractive guise before the world, led him to keep himself in the background and to take little heed that men should notice the fresh observations, deductions, and illustrations which he himself contributed towards the confirmation of Hutton's doctrines. Hence less credit has perhaps been assigned to him than he deserved as an independent and original observer. The extraordinary merit of his volume was at once recognised, and it gave a powerful impulse to the acceptation of Hutton's views. Its admirably ordered presentation of facts, its luminous and persuasive conduct of argument, its restrained caution in the statement of theoretical propositions, its caustic yet courteous treatment of Hutton's adverse critics, and its pervading grace and elegance of diction have long since given to Playfair's treatise a place among the choicest classics of English scientific literature. It consists of two parts. Of these the first contains a broad and interesting outline of the whole geological system propounded by

Hutton; the second part is composed of a series of valuable notes, further explaining and developing various parts of that system, and containing original observations and deductions of Playfair's own, together with discussions of those published by other writers. This volume brought Hutton's "Theory of the Earth" within the comprehension and appreciation of even the most unscientific reader. It not only revealed to mankind what a genius had passed away in Hutton, but it traced out with admirable clearness some of the chief routes along which geology has since travelled, and it imparted to the infant science much of the impulse which has carried it to the position which it now holds in the circle of human studies.

In Playfair's glowing pages the excellences and the defects of his master's system are faithfully reflected. Never before had so eloquent and convincing a sketch been given of the co-operation of underground and superficial agencies in the decay and renovation of land, and in the perpetuation of the conditions that make this planet a habitable globe. No previous writer had set in so clear a light the sculpture of the land by the flow of rain and rivers across its surface. Nor had the proofs of the presence of abundant intrusive igneous rocks in the crust of the earth ever been so convincingly marshalled, and this too at a time when the doctrine of Freiberg everywhere prevailed that all these rocks have been deposited either as precipitates or as sediments on the floor of the sea.

His close personal association with Hutton had given Playfair a keen appreciation of the vivid interest of geological questions and of the nature of the evidence required for their solution. His own philosophical temperament enabled him to form a calm judgment of the relative value of the various lines of proof, and to trace with precision the limits within which deductions might be logically drawn from them. Moreover, his excursions into the field under the guidance of his master had given him a quickness and accuracy of observation which in the end made him an excellent field geologist, so that in his exposition of Huttonian principles he is able from time to time to appeal in their support to evidence which he has himself collected. His "Notes" are thus full of personal interest in their revelation of his extensive acquaintance with actual concrete examples of the phenomena described.

It was Playfair who first pointed out that "for the moving of large masses of rock, the most powerful engines without doubt which Nature employs are the glaciers," and who first maintained, in opposition to De Saussure's invocation of some great debacle, that the erratic blocks, scattered in such numbers over Switzerland, have been dispersed by glaciers and rivers (§§ 348–353). His reasoning against the appeal to some great cataclysm in explanation of such phenomena enabled him to sustain with much force Hutton's protest against the tendency to have recourse to "accidental and unknown causes." In a convincing argument he reviewed the hypothesis of Buffon and Pallas as to the distribution of abundant remains of large mammals over the plains of Siberia, and he showed that these remains cannot have been brought either by an inundation of the

sea or by a deluge on land, but that the species of elephant, rhinoceros, and other animals inhabited these northern regions, where by their natural constitution they were fitted to endure the severity of the Siberian climate. "The rhinoceros of Wilui," he remarks, "certainly lived on the confines of the Polar Circle, and was exposed to the same cold while alive, by which, when dead, its body has been so long and so curiously preserved" (§ 417). He concluded his argument by suggesting that the crowded aggregates of these mammalian remains may have been connected with the migrations of the animals.

Another subject which has been much discussed since Playfair's time—the origin of lakes—did not escape his keen scrutiny of the surface of the land. It received from him a candid and cautious handling, which has not always been imitated by his successors in the discussion of this question. He recognised that "a lake is but a temporary and accidental" feature in topography, seeing that it is obviously being filled up by the unceasing transport of sediment into it from the surrounding ground, and hence that it must be "but modern compared with many of the revolutions that have happened on the surface of the earth" (§§ 319, 326). But when he tried to picture to himself the natural process whereby the lake has been formed, he had frankly to admit the difficulty of the problem. "Some cause," he remarks, "seems to act, if not in the generation, yet certainly in the preservation of lakes, with which we are but little acquainted" (§ 325). He suggests two possible modes of their origin. In the first place, they may arise from the solution and removal of such a soluble material as rock-salt, and he foretells that this must eventually happen in the salt district of Cheshire. He adds that some effect of the same kind may have taken place on the site of the Lake of Geneva, near to which salt-springs rise to the surface. In the second place, he points out that lakes may be produced by the unequal elevation and subsidence of land, whereby hollows arise on the surface which become water-filled basins (§ 327). There can be no doubt that both these suggestions indicate *veræ causæ* which have at different times and places given rise to lakes. Playfair evidently could not conceive that any natural agency can excavate basins out of solid rock. Though he had recognised the great transporting power of glaciers, he did not perceive that they also possess an erosive capacity which enables them to grind down, smooth, and polish the hardest rocks, and under peculiar conditions to hollow them into basin-shaped cavities, which on the retreat of the ice become tarns or lakes.

Like Hutton, Playfair exaggerated the influence of underground heat in the formation and consolidation of rocks. Thus he adopted and stoutly maintained his master's contention that flints and agates have been introduced in a molten condition into the rocks among which they are found. He never grasped the idea of the great solvent power of water and the permeability of rocks by aqueous solutions. Hence he deliberately rejected the proposition that consolidation of rocks may be brought about by infiltration

(a proposition so well enforced by Lamarck), and he continued to invoke the action of subterranean heat, amounting sometimes to the point of fusion, even for such deposits as rock-salt.

Another serious defect in the Huttonian theory was strenuously upheld by its illustrator. Hutton had done good service by insisting upon the igneous and intrusive nature of many rocks in the crust of the earth, though some of the evidence on which he relied was fallacious. Having convinced himself that the sparry structure of limestone and other rocks and minerals points to the action of great heat within the terrestrial crust under so vast a pressure as to prevent the escape of the carbonic acid of the carbonates, he inferred that the kernels of zeolite, calcite, and chalcedony in the cavities of amygdaloids are a proof that these rocks have been injected in a molten condition into the crust, and never reached the surface. Playfair called them 'unerupted lavas,' and believed them to be distinguishable from superficial or truly 'erupted lavas' by their enclosed kernels of calcite and other minerals, which are absent from lavas poured out at the surface. He would not admit that any of these older masses could be true superficial lavas which might have been discharged over the sea-bottom and buried under later marine sediments. He quoted, only to reject, the just observation of Spallanzani that the amygdaloids of the Euganean Hills are true superficially ejected lavas, the steam cavities of which have been filled with minerals deposited by infiltrating water (§ 234). He was evidently much impressed by the singularly interesting and suggestive account given by Dolomieu of the intercalation of successive sheets of lava among the limestones of Sicily, but he would not admit that these lavas were poured out over the sea-bottom as "imagined" by Dolomieu. He did not see that by admitting the probability of ancient "submarine volcanoes" he would in no way have invalidated the proofs of intrusion demonstrated by Hutton, but would have obtained a new argument in favour of his master's doctrine of the continuity and antiquity of Nature's operations (§§ 242–244).

To Playfair belongs the merit of having first exposed the gross error of those Neptunists who, in support of their opinion that basalt is a rock which was deposited from solution in water, cited the basalt of Port Rush in the north of Ireland as containing fossil shells. His practised eye soon detected the source of the blunder, a dark shale containing ammonites having been mistaken for the basalt which had invaded and greatly indurated it.[1]

One of the most memorable "Notes" to the "Illustrations of the Huttonian Theory" is that in which the author, discussing the causes of the apparent changes in the level of the sea, maintains that on the whole it is the land which rises or sinks, and not the surface of the sea (Note xxi). It would be difficult to exaggerate the importance of this contribution to geological literature. Although

[1] Playfair's examination of the specimens from Port Rush was made in company with Lord Webb Seymour and Sir James Hall ("Illustrations," § 253).

Playfair's generalisation was no doubt too unqualified, seeing that he failed to recognise other influences which more or less affect the level of the sea, there can be no doubt that his argument, so cogently and temperately urged, at once introduced simplicity into the consideration of many geological problems which had up till then been involved in much confusion, and that in this way it greatly helped the onward advance of the science.

After the publication of his geological volume Playfair made many journeys in the British Isles and abroad for the purpose of visiting places of geological interest and of gathering materials towards the preparation of a new edition of that work. In particular, after the conclusion of peace, he undertook a prolonged journey on the Continent, and though then 68 years of age, he travelled through France, Switzerland, and Italy, as far as the volcanic region of Naples. He was absent from Scotland for seventeen months, and in his journeys travelled a total distance of some 4,000 miles. The quotations from his notebooks given in the brief biographical notice of him prefixed to the collected edition of his works are so replete with original and important observations as to fill us with the deepest regret that he never lived to embody them in an amplified re-issue of his admirable volume. Had he been able to accomplish his design, there can be little doubt that he would thereby have given a further impulse to the progress of the science which he loved and to which he devoted so large a part of the last years of his life.

In concluding this address I should like to point out how well the lives of the two distinguished men which we have now been tracing illustrate many of the distinctive aspects of scientific research. They show the fascination exerted by the study of Nature, and the devoted enthusiasm of those who give themselves up to this study and pursue it with a self-abnegation almost heroic in its indifference to everything but the establishment of the truth. Lamarck and Playfair were engaged in the investigation of the same problems, and had the political conditions of Europe at that time been more favourable they would doubtless have made themselves conversant with their mutual researches, and in all likelihood would have entered into correspondence with each other, if not into the personal relations which the Peace of Amiens had for a few months made possible.

Among the changes in the last century resulting from the remarkable development of facilities for travel, one specially worthy of remark has been the continual growth of sympathy and friendship among men of science in every part of the world. By their community of interest in the study of Nature these men are linked in a brotherhood of peaceful and serious work. For science belongs to no country, or rather she is the common heritage of every country. She knows no politics, and pursues her calm career under the most autocratic despotism as well as under the most democratic republic. She does not employ only one language, but makes her voice heard in the native tongue of every civilised land. Hence it has come

about that those who cultivate science are perhaps the most cosmopolitan men in our modern world. They come from all corners of the globe to organise themselves in congresses for the purpose of discussing and promoting the subjects in which they have a common interest and in regard to which they can render each other mutual assistance. Their learned societies and academies rival each other in their generous recognition of the labours of foreign fellow-workers. If the Académie des Sciences in Paris inscribes in its roll of honour, as correspondents and associates, the names of the most distinguished men of science of all countries, the Royal Society of London does not lag behind in the choice of its foreign members and in the bestowal of its medals without respect of nationality.

Hence there cannot be any doubt that the desire to draw together the cultivated society of France and Great Britain in friendly and personal relations (which is the aim of the "Alliance Franco-Britannique, littéraire, scientifique, et artistique") has already long ago been accomplished by men of science. If these men on the two sides of the Channel are rivals, it is in the warfare against ignorance and in the noble task of building the vast temple of science which by their joint labours and those of their associates in other lands is slowly but surely rising in the midst of mankind.

Seeing, then, that as men of science we have experienced the inspiration and the pleasure of mutual co-operation with our fellow-labourers abroad in the same pursuits, we welcome with the heartiest cordiality the establishment and growth of sympathy and friendship between the peoples of France and of Great Britain. Most sincerely do we hope that the same spirit of mutual respect and active brotherhood which has so long reigned in the scientific world may spread through all ranks of society, until the two united nations shall be able to speak to the world with one single voice in the cause of liberty, of progress, and of peace.

To render even a feeble service towards the promotion of this great international movement of our time must be regarded as at once a duty and a pleasure. For myself, I am proud that permission has been granted to me to speak in behalf of such a cause in the halls of the Sorbonne, for so many centuries a favourite home of Philosophy and Science, and I am happy to avail myself of this opportunity of offering my tribute to the memory of the illustrious men who within these walls have created one of the intellectual centres of the world and have linked mankind together in ties of gratitude and admiration for the genius of France.

II.—On the Occurrence of the Genus *Dimyodon*, Mun.-Chalm., in the Mesozoic Rocks of Great Britain.

By Dr. K. A. Grönwall, of the Geological Survey of Denmark, Copenhagen.

WHEN looking through the number of the Quarterly Journal of the Geological Society for August, 1905, I saw the paper by Mr. Richardson on the Rhætic deposits of Glamorganshire and his figure of *Plicatula intusstriata*, Emmr. At the first glance it

struck me that this fossil was closely allied to a group of bivalves, well known to me as occurring in the Chalk, where it is represented by the genus *Dimyodon*, Munier-Chalmas.

In 1842 von Hagenow[1] described, under the name *Ostrea Nilssoni*, a bivalve shell found in the White Chalk of Rügen, attached to several other fossils, e.g., belemnites, oysters, and sea-urchins. Although he gave parallel diagnoses of this shell and *Ostrea hippopodium*, Nilss., he did not see the generic difference between his fossil and the oysters.

Later on, 1891, J. Böhm[2] referred *Ostrea Nilssoni* to the genus *Dimyodon*, Mun.-Chalm., and in the same year Stolley[3] described a new species, as also did I myself in the year 1900,[4] then figuring the three Danish species that all occur rather commonly in the Chalk of North-Western Germany and Denmark, *D. Nilssoni*, von Hag., *D. Böhmi*, Stoll., and *D. costatus*, Grönw.

This group of fossils also occurs in the British Chalk. *D. Nilssoni* was in the year 1864 described by S. P. Woodward[5] under the name *Plicatula sigillina*, S. P. Woodw. H. Woods, in his recent monograph of the British Chalk Bivalves,[6] having in the description of 1901 (Pt. iii, p. 143; pl. xxvi, figs. 19–22) used S. P. Woodward's name, in an addition of 1903 (Pt. v, p. 225) altered it into the current name, *Dimyodon Nilssoni*.

When writing the note on *Dimyodon* in 1900 I found in the collections of the Museum of Copenhagen some British specimens of *D. Nilssoni*, v. Hag., and also one of *D. Boehmi*, Stoll., fixed on a *Micraster cor-testudinarium*.

During a visit to England in the Summer of 1905 I saw in the British Museum, besides several specimens of *D. Nilssoni* from various localities, one specimen of *D. Boehmi*, or a closely allied form, fixed on an *Echinocorys* from the Upper Chalk of Gravesend, Kent, and of Grays, Essex.

In the collections in Copenhagen I had also seen some specimens of this genus from the Jurassic fixed on other fossils of greater importance and themselves never determined. In the Geological Museum of Bath some specimens of *Dimyodon*, growing on a *Lima* from the Lower Lias, attracted my attention. They were labelled *Plicatula intusstriata*, and the localities were Shepton (Somerset), Southerndown and Bridgend (Glamorganshire). There was also a smaller species of *Dimyodon* fixed on a *Lima* from the Upper Lias. I had no opportunity of an examination, but only surveyed them as they were exhibited in the show-case.

Later on, in the paper of Mr. Richardson[7] I met with the excellent figure of the *Plicatula intusstriata*, Emmr., clearly proving

[1] Neues Jahrb. f. Min., 1842, p. 546.
[2] Palæontographica, vol. xxxviii (1891), p. 89, pl. iv, fig. 7.
[3] Mitth. Min. Inst. Univ. Kiel, vol. i (1891), tome vii, p. 243, pl. vii, fig. 8.
[4] Medd. dansk geol. Foren., No. 6 (1900), pp. 73–80, pl. ii, figs. 1–8.
[5] Geol. Mag., Vol. I (1864), p. 112, Pl. V, Figs. 1–5.
[6] A Monograph of the Cretaceous Lamellibranchia of England (Palæont. Soc., 1899–1903).
[7] Q.J.G.S., vol. lxi (1905), p. 423, pl. xxxiii, fig. 1.

that this fossil belongs to *Dimyodon*, as this genus is represented by the above-mentioned Cretaceous species.

As it is obvious that this series of forms is widely distributed in the Jurassic rocks of Great Britain, as well as in the Cretaceous, I wish to call the attention of British geologists to these fossils. It would be a promising task to subject the genus and such allies as may hide among the numerous obscure *Plicatulæ* and *Ostreæ* to a thorough revision, but as I have neither the necessary time nor material and literature at my disposal I will only give some hints on this matter.

The genus *Dimyodon* was established by Munier-Chalmas in the "Manuel de Conchyliologie" of Fischer, 1887, p. 937, and its type is *D. Schlumbergeri*, Mun.-Ch. (l.c., fig. 705), from the Bathonian of Hérouvillette. Fischer considers *Dimyodon* as a subgenus of *Dimya* Rouault, but Zittel [1] seems to regard these two genera as identical.

I am inclined to place the following species in the genus *Dimyodon*, but, as already mentioned, this enumeration in no way claims to be complete.[2]

A.—Jurassic.

1. *D. intusstriatus*, Emmr. A very widely distributed species in the Rhætic and the Lower Lias. In the Alps it was first found and therefrom described by Emmrich [3] (the "Kössener Schichten" of the Northern Alps). Its distribution in France is unknown to me, but Mr. Jean Miquel, of Barroubio par Aiguesvives, has kindly communicated to me a specimen from Villespanans (Hérault) from the *Avicula contorta* zone. As to its distribution in Great Britain, I am indebted to Mr. Richardson for very minute records; *D. intusstriatus* has its maximum in the White Lias, but ranges from the *Avicula contorta* zone to the *Bucklandi* zone. Mr. Richardson has found it in Devon, Somerset, S. Gloucestershire, and Glamorganshire. According to R. F. Tomes [4] it occurs also in Warwickshire.

2. *D.* (?) *retifer*, Eudes-Deslongchamps. Mr. Miquel communicated to me a specimen of this fossil (which I only refer to this species on the faith of his determination) from the Upper Bathonian of France, "falaise de St. Aubin sur mer, Calvados." It was determined as a *Plicatula*, but there is no doubt of its belonging to *Dimyodon*.

3. *D. Schlumbergeri*, Munier-Chalmas. This species, the genotype, is found in the Bathonian of Hérouvillette, France, and is figured in Fischer's "Manuel de Conchyliologie" (l.c.).

4. *D. striatissimus*, Quenstedt,[5] from the Malm of Germany, White Jura γ.

[1] "Grundzüge d. Paläontologie," Zweite Auflage, 1903, p. 292.

[2] Besides that some species may be concealed among *Plicatulæ* and *Ostreæ*, I may here mention that Mr. Munier-Chalmas in 1897 told me, in a letter, that there were still some undescribed Jurassic species of *Dimyodon*.

[3] Jahrb. d. k. k. geol. Reichsanst., vol. iv (1853), p. 376.

[4] Q.J.G.S., vol. xxxiv (1878), p. 182.

[5] "Der Jura," 1858, p. 628, pl. lxxviii, fig. 4. The author also figures a *Plicatula* sp. (pl. lxxviii, fig. 5) from the White Jura β; it belongs to *Dimyodon*.

B.—Cretaceous.

5. *D. Boehmi*, Stoll.[1] This widespread species occurs in the Senonian of Northern Germany, Denmark, and England, and is also found in the Danian at Faxe, Denmark.

6. *D. costatus*, Grönw.[2] Common in the Senonian of Denmark, Sweden, and Northern Germany; also found in France, at Meudon. In the Danian there is found a form that in some points differs from that of the Senonian.

7. *D. intusradiatus*, Gümbel.[3] Upper Chalk of the Bavarian Alps.

8. *D. Nilssoni*, v. Hag.[4] This species has a very great extension vertically as well as horizontally. It ranges from the Upper Gault of Folkestone to the Danian of Denmark. It occurs abundantly in the Chalk of England, Northern France, North-Western Germany, the Northern Alps, Denmark, and Sweden.

As to the systematic position of the genus *Dimyodon* as here defined, authors are not quite in agreement, mainly because these fossils occur in a rather imperfect state of preservation, and because the free valve is but rarely found. The cardinal parts of the shell are commonly—as a rule in the young ones—inconspicuous and obliterated, while the muscular impressions, in the Cretaceous forms at least, are almost unknown. The ridge-formed teeth, however, sufficiently prove the hinge mechanism to be isodont and these fossils to be allied to the Spondylidæ.

Some authors[5] have considered *D. Nilssoni* to belong to the genus *Cyclostreon*, Eichwald,[6] the type of which is the *Ostrea plicatuloides* of Leymerie.[7] According to the rather obscure description, the genus *Cyclostreon* is characterized by the absence of proper cardinal teeth and muscular impressions, in place of which there is a horse-shoe-shaped impression which serves for the reception of ligament and the junction of the valves.

This interpretation may be the right one for the original species, *O. plicatuloides*, Leym.; but for the fossils here mentioned I may deny the possibility of assigning them to the genus *Cyclostreon* as defined by Eichwald. Frauscher[8] has in the genus *Cyclostreon* associated some most heterogeneous species, among which two species of *Dimyodon*, *D. intusstriatus*, Emmr., and *D. intusradiatus*, Gümb., are to be found.

The Cretaceous species of the genus *Dimyodon* form a well circumscribed and strictly defined group, and, so far as I know the Jurassic species, it seems to me that the same will apply to them.

[1] Stolley: loc. cit. Grönwall: loc. cit., fig. 8.
[2] Grönwall: loc. cit., figs. 4–7.
[3] Palæontographica, vol. xxxviii (1891–2), p. 88, pl. iv, figs. 2*a–c*.
[4] Grönwall: loc. cit., figs. 1–3. Woods: loc. cit.
[5] Vogel, 1895: in Sammlungen d. geol. Reichsmuseum zu Leiden, neue Folge, herausgegeben v. K. Martin, vol. ii, tome 1, p. 14, pl. i, figs. 4–7. Wegner: Zeitsch. d. deutsch. geol. Gesellsch. Jahrg., 1905, p. 175.
[6] Lethæa rossica, vol. ii, pp. 406–7.
[7] Mém. Soc. géol. France, sér. II, tome iv (1851), p. 195, pl. ix, figs. 17*a–e*.
[8] Denkschr. k. Akad. Wiss., Math. Nat. Cl., vol. li; Wien, 1886.

III.—On the Relation between the Older and Newer Palæozoics of West Cornwall.[1]

By J. B. Hill, R.N., of the Geological Survey.

(PLATE XIV.)

Introductory.

THE author, who has long been engaged on the Palæozoics of West Cornwall, divided the killas extending westward from Gerrans Bay into four groups that formed a natural sequence.[2] Moreover, as they included definite Lower Silurian horizons, as characterized by the fossiliferous quartzite of Carne, these divisions were linked with the Lower Palæozoics. They consist of the Veryan, Portscatho, Falmouth, and Mylor groups. On the latest issues of the old Survey maps the area occupied by the first of these divisions is coloured as Silurian, and the region occupied by the remainder as Devonian. That colouring, however, was not adopted by De la Beche, who surveyed the region, nor was it the result of any subsequent survey of the area. In the original Geological Survey map of Cornwall the killas was separated by De la Beche into two divisions, viz., a grauwacke group and a carbonaceous series. Thus, the former lying below the Culm-measures was undifferentiated for the reason, as explained in his Report,[3] that the progress of geology at that time only warranted the broadest generalizations. He moreover expressed the opinion that the terms Cambrian and Silurian should be restricted to the areas that gave rise to the prolonged researches of Murchison and Sedgwick, and deprecated the extension of that nomenclature to districts that had not received the same detailed investigations. In a later and undated issue of the map the grauwacke group is divided into Devonian and Silurian, presumably by the authority Sir Roderick Murchison. The Devonian colour was not only applied to fossiliferous strata in East and Mid Cornwall, but was extended over the unfossiliferous strata in the west. The Silurian tint, on the other hand, was restricted to a zone that had yielded organic remains. Murchison, however, was of opinion that the older zone extended far beyond those limits into the barren strata coloured as Devonian,[4] and it is evident that the latter tint was adopted as a matter of convenience, as no re-examination of the area seems to have been undertaken. The known Silurian region was confined to the coastal belt between Chapel Point and Gerrans Bay, a boundary connecting those localities admitting of the ready isolation of that zone from the rest of the country. That such a broad generalization, however, was only regarded as provisional may be inferred from the absence of a line on the map between the two divisions. It will be seen, therefore, that the subdivision of the killas, as the result of the

[1] Communicated by permission of the Director of the Geological Survey.

[2] Summary of Progress, 1898, p. 97, and Trans. Roy. Geol. Soc. Cornwall, vol. xii (1901), pt. 6.

[3] "Report on the Geology of Devon, Cornwall, and West Somerset," pp. 38–41.

[4] Trans. Roy. Geol. Soc. Cornwall, vol. vi, p. 322.

recent survey, neither invalidates the map published by De la Beche nor the subsequent conclusions of Murchison. It has, on the other hand, not only brought their generalizations within more definite limits, but has carried the investigation a step farther by demonstrating the relations between the older and newer Palæozoics of Cornwall.

As the lithological characters, the structural features, and the mutual relations of the divisions into which the killas has been differentiated have already been the subject of former communications, both to the Royal Geological Society of Cornwall[1] and to the Summaries of Progress of the Geological Survey,[2] they will only be treated briefly in this paper. They will, moreover, be fully described in the Survey memoirs, but, as the results of recent investigations constitute an important advance in the elucidation of the geology of the West of England, it will be convenient to present at once an outline of these conclusions, as the official publications will not be immediately forthcoming.

The main object of this paper is to demonstrate the existence of an important unconformity dividing the Upper and Lower Palæozoic formations of West Cornwall. Evidence will also be submitted pointing to the natural sequence of the four divisions of the Lower Palæozoics, and to the Lower Devonian age of the conglomeratic series of Manaccan and Grampound.

Lithology of the Lower Palæozoic divisions.

The lithological characteristics of the divisions will now be briefly touched upon.

Veryan Series.—This group consists of blue and grey slate with sandy alternations, thin dark limestones, and dark-coloured cherts. Notwithstanding the occurrence of chert and limestones the sandy interlaminations are frequently coarse, but being largely composed of soft grains are readily cleaved. This series, which also includes the Carne quartzite, is further characterized by the presence of manganese, which stains the slate.

Portscatho Series.—These consist of blue and grey clay slates, alternating with harder beds showing every gradation from a sandy slate to a fairly strong grit. The latter are characterized by the predominance of quartz and the comparative abundance of clastic mica. The marked feature, however, which distinguishes them from the Veryan Series is the absence of limestone, except at their mutual junctions. This dearth of calcareous material also applies to the Falmouth and Mylor divisions.

Falmouth Series.—This series consists of argillaceous and fine sandy alternations, varying in colour from green to grey and buff, although blue argillaceous beds sometimes appear. The contrasting tints produce a variegated appearance common to this group. Their mode of decomposition is equally characteristic. The sandy seams become readily friable, are unctuous to the touch, and weather into

[1] See paper already cited.
[2] From 1897 onwards.

a deep buff colour. The material is of finer texture than the Portscatho Beds, and the coarse structure often seen in the latter is not represented. The presence of zones of strongly contrasted purple and green slate is likewise a distinctive characteristic of this group.

Mylor Series.—This division consists of blue argillaceous and fine-textured sandy beds. The latter are often very siliceous, and occasionally thin quartzites are developed. The most distinguishing feature of this series is its striped and ribbon-like appearance, due to fine alternations of siliceous and argillaceous material, or to argillaceous laminæ varying in composition and colour. This composite structure, while a marked characteristic of this division, is frequently developed both in the Portscatho and Falmouth divisions. In this series it has often contributed to the production of pseudo-conglomerates, following conditions of stress.[1]

Natural sequence of the Lower Palæozoic divisions.

The four divisions already referred to pass uninterruptedly into one another without any stratigraphical break. The junction between the Veryan and Portscatho groups is well exposed at Pendower in Gerrans Bay. Although the two groups there occupy adjoining horizons, and the former are coloured as Silurian and the latter as Devonian in the old map to which attention has been drawn, their natural sequence is demonstrated by the gradual dying out of the Veryan limestones to the west, and which are still represented in an attenuated form within the Portscatho Series, thus serving as a connecting link between the two groups. Not only do the Veryan Series pass uninterruptedly into the Portscatho group, but these latter also graduate imperceptibly into the Falmouth Series, which in their turn merge insensibly into the Mylor Beds. Notwithstanding the comparative absence of palæontological data the researches of Mr. Howard Fox and Dr. Hinde on the Radiolaria tend to confirm the unbroken sequence of these deposits. The Radiolarian remains have been determined by Dr. Hinde from localities scattered throughout these divisions, but these organisms have not been detected on any known Devonian horizon. Besides Radiolaria, Crinoidal and other fragments are occasionally found in these divisions,[2] but their occurrence is extremely rare. The quartzite of Carne in Gerrans Bay, which has yielded Caradoc fossils, was included within the Veryan Series, as it appeared to fall naturally into that division.[3] The detailed investigation of that area has been subsequently undertaken by Mr. Reid, whose results do not invalidate that sequence.

Relations of the Newer and Older Palæozoics in the Manaccan area.

Having now given a brief outline of the Lower Palæozoic divisions, in so far as they have been investigated by the author,

[1] An account of these structures will be found in the Trans. Roy. Geol. Soc. Cornwall, vol. xii (1901), pt. 6.

[2] Excluding the Carne quartzite.

[3] J. B. Hill: Trans. Roy. Geol. Soc. Cornwall, vol. xii (1901), pt. 6.

their precise relations with the Devonian formation will now be discussed. While engaged last season on the survey of the tract bordering the Helford basin, the killas was carried south to Porthallow and westward as far as Tregidden. At Porthallow a fault divides the killas on the north from mica-schist on the south. The rocks lying to the south of that disturbance are not dealt with in this paper.

The sedimentary divisions from the Carnmenellis granite, on the north-west, to Porthallow on the south-east, occur in the following topographical order:—

Mylor Series.
Falmouth Series.
Portscatho Series.
Manaccan Series.
Veryan Series, including the Quartzite.

Of these groups the Manaccan Series represents the Newer Palæozoic,[1] and the remainder are confined to the Older Palæozoic. The strike of the latter is about north-east and south-west, while that of the former is slightly oblique and approximates to an east and west direction.

The Mylor Series, through which the granite has intruded, occupies a band gradually widening in a south-westerly direction from Porthnavas to Gweek. Excellent coast sections across the entire band are afforded by Polwheveral Creek, showing the whole metamorphic aureole as well as the zone beyond.

The Falmouth division that succeeds to the south-east forms a narrow band, but widening likewise in a south-west direction. It extends from Mawnan Smith to Mawgan Creek, and is almost entirely confined to the north side of Helford River. Besides the main zone, infolded lenticles occur in the vicinities of Helford, Durgan, and Bream Cove. Excellent transverse sections are exhibited along the coast at Calamansack.

The Portscatho Series succeeds the Falmouth group to the south-east and forms the coastline as far south as St. Anthony. To the westward it practically monopolises the southern side of Helford River, and the northern shore as far as Porthnavas Creek. It also reappears as a small strip at Porthallow, where it is separated from metamorphic rocks of the Lizard type by a fault.

The Manaccan Series.—The natural sequence represented by these three Lower Palæozoic groups is now broken, and another assemblage makes its appearance, which may be designated the Manaccan Series. It rests unconformably on the Portscatho and the Veryan divisions (including the Carne quartzite), and is largely made up of their detritus. The group occupies a band extending westerly from the coast at Nare Point, whence it has been mapped, as far as St. Martin. Passing to the north of Manaccan it is seen along the shores of Gillan Creek, and around the Nare Point to a little beyond the Nare Head. Its southern margin from the coastline to Treglossack skirts the Veryan Series, and thence to the

[1] The evidence in support of this assumption will be given later.

westward is in contact with the Lizard group. Besides this main outcrop small infolds also occur amongst the Veryan Series. Lithologically, the group consists of conglomerate, sandstone, and clay slate, the two latter being often calcareous, and they are all so clearly interbedded that their natural sequence is obvious. The most important member is undoubtedly the conglomerate, from the evidence it affords of the derivation of the group. Its character and main constituents have been given in a former publication,[1] since which it has yielded chert, mica-schist, and possibly serpentine. The latter ingredient, however, being obtained from a road section, the evidence is possibly not conclusive. At its northern margin, where the conglomerate is in close relation with the Portscatho Series, it is almost entirely composed of fragments derived from that group. This is admirably exhibited at Gillan harbour, where the magnitude of the boulders, often exceeding a foot in size, enables their ready identification with the Portscatho Beds in their immediate vicinity, in which practically every type of the latter is seen to be incorporated. The fact, moreover, that the fragments were veined with quartz prior to such incorporation sufficiently indicates the magnitude of the break represented by this unconformity. The conglomerate is likewise seen in contact with the Portscatho Beds on the coastal shelves at Men-aver Point and Nare Point. It has been remarked that the conglomerate varies with the nature of the underlying rock from which it is derived. Whereas at Gillan Creek, where it rests on the Portscatho Series, fragments of that group preponderate, as the Veryan Series and quartzite horizons are approached it partakes more of the character of those types, and the foreign fragments derived from the Lizard rocks increase in a similar direction. The conglomerate is by no means continuous, but the base of the formation is frequently of fine texture. This is shown by the protruding bosses of quartzite, some of which are encircled by the sandstone beds of the Manaccan Series. There is, moreover, a tendency for the coarser deposits to die out in a westerly direction, as was long ago recorded by De la Beche,[2] the frequent absence of which presents difficulties in the demarcation of the Manaccan Series from the older Palæozoics that underlie them, and especially where good sections are not available.

The Manaccan Series present a less advanced type of metamorphism than that of the Lower Palæozoic divisions amongst which they occur. This difference in deformation between the older and newer Palæozoics, although not always of a very marked type, was early recognized by the author as a significant factor, more especially in the comparison of the killas of Mid Cornwall with that occupying the western regions, which pointed to the conclusion that the latter represented conditions of stress that were either not experienced by the former or prevailed in a less vigorous degree. In the Manaccan area this contrast is admirably illustrated by the comparatively unaltered condition of the clay slates associated with the

[1] J. B. Hill: Trans. Roy. Geol. Soc. Cornwall, 1901.

[2] "Report on the Geology of Cornwall, Devon, and West Somerset," 95.

conglomerate and the more advanced type of deformation represented by the adjoining Portscatho and Veryan divisions. Mr. John Pringle has obtained numerous plant remains from these rocks, together with a few corals and brachiopods, but beyond indicating a marine fauna they throw no light on their geological age. The argillaceous members were searched for graptolites, but without success.

The Manaccan Series is also characterized by the presence of a basic lava that occupies a well-marked horizon between Roskruge and Tregidden. Its contemporaneous nature is clear, not only from its having been involved with the coarser deposits, and frequently partaking of a conglomeratic margin, but scoriaceous boulders clearly derived from it have been incorporated with the adjacent conglomerate. The rock is a very fine-grained basalt, often andesitic, and belongs to the 'pillow lava' class. As this rock is the sole greenstone in West Cornwall that can be definitely separated from the intrusives, it is possible that the contemporaneous greenstones are restricted to the Devonian.[1] Moreover, its comparatively undeformed condition still further illustrates the less advanced metamorphism presented by the Devonian rocks to that of the Lower Palæozoics.

The Veryan Series of Meneage.—The quartzite is almost entirely hidden beneath the Manaccan Series, through which it emerges in numerous lenticles from Penare on the east to Trevaddra on the west. Besides being veined with quartz it is often extremely brecciated, but in this condition loses nothing in compactness, the interstices being filled up with silica. This character was attained prior to the formation of the overlying conglomerate.

The Veryan Series is exposed along the coast from a little north of Nare Cove to Porthallow Cove, whence it extends inland as far as Treglossack, and is there overlain by the Manaccan Series. This small tract is highly disturbed, while local thrusts and brecciation with production of pseudo-conglomerate are prevalent, and it is, moreover, not solely confined to the Veryan group. The quartzite appears between Nelly's Cove and Porthallow Cove. Thin limestones are seen from Nelly's Cove to Nare Cove. Radiolarian cherts are distributed over the section, and are strongly developed at Nelly's Cove. The Portscatho Series and strips of the overlying conglomerate can also be detected, more especially at the south of Porthallow Cove, where the former is contiguous to the Lizard group. It is probable also that this highly disturbed tract may contain representatives of other zones,[2] but the Veryan Series undoubtedly preponderates. At Gallentreath, between Nelly's Cove and Porthallow Cove, a greenstone of pillow lava type is seen that recalls the pillow lava of Mullion Island. Another highly silicified igneous rock that is closely adjacent resembles a similar band mapped by Mr. Reid at Perhaver. Like the rock at Mullion Island, the Gallentreath

[1] The evidence pointing to the Devonian age of the Manaccan Series will follow.

[2] Geol. Mag., 1904, No. 481, in which Mr. C. D. Sherborn has referred fossils obtained from this district to Ludlow age.

greenstone is in close proximity to Radiolarian cherts, but the evidence is insufficient to decide whether it is intrusive or contemporaneous.

The Devonian base on the Grampound and Probus horizons.

The evidence obtained from the Manaccan area, where the Upper Palæozoic rocks occur as a great outlier amongst the Lower Palæozoic group, has thrown light on the nature of the junction further to the north that marks the main boundary between those formations. The fine-grained conglomerate of Grampound and Probus was recognized in 1902 as the equivalent of the conglomerate of the Manaccan Series. This inference was amply confirmed by microscopical determination undertaken by Dr. Flett. It contains a similar assemblage of rock fragments, resembling one another so closely as practically to preclude the possibility of their derivation from different sources, or from the same source at widely different periods. It was at the same time recognized that it might represent an unconformity between the Silurian and Devonian rocks of Cornwall, an inference which the recent detailed investigation of the Manaccan area has shown to be correct. This fine-grained conglomerate is associated with slightly calcareous sandstones and clay slates, and the whole assemblage is precisely equivalent to that represented by the Manaccan Series, except that in the latter, besides the fine-grained conglomerates like those of Probus and Grampound, these beds frequently present an extreme coarseness, many of the included boulders exceeding a foot in size. As already remarked, the conglomerate of that area is by no means continuous, but the base of the formation is frequently of fine texture. There is, moreover, a tendency for the conglomerate to die out in a westerly direction, so that the demarcation of the Manaccan Series from the older Palæozoics is attended with difficulty in the cultivated areas. These conditions are exactly reproduced in the Probus horizon. The coarse conglomerates, analogous to those of Manaccan, occurring only in the district further to the east, where they have been mapped by Mr. Reid in the Gorran Sheet (353), while in the western direction towards the Bristol Channel even the fine-grained conglomerates of Probus and Grampound disappear. The rock series of Probus likewise corresponds in strike with that of Manaccan, having a general east and west trend and oblique to that of the adjoining Lower Palæozoic strata. The southern boundary extends from Porth Towan on the west to Probus on the east, whence it has been traced by Mr. Reid to the north of Tregoney, where it sweeps to the south, and thereafter follows an irregular course to the coast at St. Michael Caerhayes.

The Grampound and Probus Beds have hitherto yielded no organic remains except at Ladock, where an indeterminable brachiopod has recently been discovered. To the north, however, the work of Messrs. Reid and Scrivenor shows that they link on with Lower Devonian fossiliferous horizons in the Newquay district. They, moreover, have close affinities to the Devonian, not only in their

prevailing strike, but also in lithological type and metamorphic condition. For these reasons they are taken to represent the basement beds of that formation.

Relative deformation of the Older and Newer Palæozoics.

It has already been pointed out that the Lower Palæozoic rocks exhibit a greater degree of deformation than do the overlying Devonian. It can be shown by the included boulders in the Devonian conglomerate that the Caradoc quartzite was brecciated and the interstices cemented by silica prior to their incorporation in that deposit. It has likewise been shown from the same evidence that the Portscatho Beds had been welded into solid rock and veined with quartz before the formation of that conglomerate. The Lower Palæozoic beds, therefore, must have been buried deep within the crust and compressed into solid rock, and subsequently upheaved to form the floor of the Devonian seas. At the close of the Carboniferous period these rocks, in common with the overlying Devonian, were again brought within the influence of crustal disturbance, by which they were folded, fractured, and cleaved. As a result of this twofold experience in the subterranean depths almost all traces of organic life appear to have been obliterated. So far as the Mylor, Falmouth, and Portscatho divisions are concerned, and even the Veryan Series if we exclude the quartzite, the sole relic of life that has survived, except an occasional crinoid fragment, is confined to the Radiolaria, the preservation of their casts being in no small measure due to the minuteness of these tiny creatures, and to the siliceous nature of the cement in which they are usually encased.

Age of the Lower Palæozoic divisions.

The age of the Lower Palæozoics cannot be precisely defined. The Quartzite is of Lower Silurian age, and palæontologists are agreed that the fauna is Caradoc.[1] If its inclusion in the Veryan group be correct—and there is no evidence at present pointing to a discordance in the sequence—there is a natural succession from the Quartzite on the one hand to the Mylor Series on the other. The discovery of Upper Silurian fossils by Messrs. Upfield Green, Sherborn, and Reid in areas closely adjoining to the Caradoc Quartzite would appear to indicate a downward succession, of which the Mylor Series represents the base, and that the Lower Palæozoic divisions referred to in this paper are Lower Silurian. As the survey, however, of the older Palæozoics in the Meneage peninsula has not yet been completed, it will be safer to defer further consideration of this subject until the evidence has been exhausted. It will be sufficient for the present to have demonstrated the limits of the Devonian, and to have shown that the killas of West Cornwall is chiefly restricted to the Lower Palæozoics, of which at least one member is of Caradoc age.

[1] The Lower Silurian age of this quartzite was proved by the late Mr. Charles W. Peach, to whose palæontological researches Cornish geology owes so much. Murchison noted that the Gorran fossils were Upper Caradoc, and those of Gerrans Bay (Carne quartzite) were even younger (Trans. Roy. Geol. Soc. Cornwall, vol. vi).

Work of other observers in the district.

The geological literature of West Cornwall is so voluminous that it would be impossible within the compass of this paper to do justice to the work of previous observers. In 1821 the Nare Point conglomerate was referred to by Sedgwick, who noted its mechanical origin and its passage into the ordinary grauwacke of the district.[1] It is evident from a perusal of De la Beche's Report, that had he differentiated the Silurian strata from the Devonian, he would have included among the former some of the killas in the Meneage peninsula. As already remarked, Murchison expressed the opinion in 1846 that much of the strata between Gerrans Bay and Falmouth would prove to be of Silurian age. The killas of West Cornwall has formed the subject of various papers by Mr. J. H. Collins, whose researches, extending over many years, prove the zeal and enthusiasm with which he attacked this thorny problem. In 1881 Mr. Collins published a sketch-map with his paper on the Geology of Central and West Cornwall,[2] in which he not only divided the killas into numerous units, but assigned them respectively to the Devonian, Upper Silurian, Lower Silurian, and Cambrian formations, that were separated from each other by unconformities. Although Mr. Collins' general conclusions cannot be sustained, he subsequently correlated the conglomeratic series of Meneage with the Ladock Beds (the latter being, in part at least, equivalent to the Grampound and Probus grits), and assigned them to the Lower Devonian.[3] He recognized also that the killas of West Cornwall was mainly of Lower Palæozoic age, and had he confined himself to that broad generalization his paper would have ensured a more lasting recognition. He also placed the Ponsanooth Beds, which to some extent represent the Mylor Series, at the base of the killas, which may probably be correct. Mr. A. Somervail[4] controverted some of Mr. Collins' conclusions, but agreed with him as to the Pre-Devonian age of a large part of the killas, and assigns a Lower Silurian age to the slates from Gerrans Bay to the vicinity of Penryn, most of which had been similarly classified by Mr. Collins, and Mr. Somervail suggested that they were of Llandeilo age. In 1891 Mr. Ussher published a sketch-map with his paper,[5] dealing with the Devonian rocks as described by De la Beche and supplemented by his own researches on that formation. In that map Mr. Ussher has likewise shown the western killas (now representing the Mylor, Falmouth, and Portscatho Series) as (?) Pre-Devonian, and has placed the Grampound grits at the base of the series classed as undoubted Devonian. Mr. Upfield Green has claimed the beds represented by the Mylor, Falmouth, and Portscatho Series as Lower Devonian, of which the Dartmouth slates represent the upper member, while the base is marked by the conglomerate

[1] Trans. Cambridge Phil. Soc., vol. i.
[2] Journ. Roy. Inst. Cornwall, vol. vii, p. 17.
[3] Journ. Roy. Inst. Cornwall, vol. viii, p. 186.
[4] Journ. Roy. Inst. Cornwall, vol. vii, pp. 262–273.
[5] Trans. Roy. Geol. Soc. Cornwall, 1891.

of Meneage, etc.[1] Mr. Green's conclusions were criticized by Mr. Ussher, who contended that the superposition of the Dartmouth slates to the Mylor, Falmouth, and Portscatho Series was not supported by proof.[2] Mr. Ussher recalled that although he formerly correlated the Grampound grits with the Gedinnien, he would now hesitate to do so, the inference apparently being that they might occupy a higher horizon. In that paper Mr. Green refers to the Portscatho and associated series as consisting "chiefly of grits varying much petrologically, but mostly felspathic," and correlates them with arkose or felspathic grits that occur next to the conglomerate on the Continent. As the conglomerate is now shown to be unconformable to the Portscatho Beds, it is of little importance to point out that the latter are more properly defined as siliceous grits, in which felspathic constituents play only a subordinate part, so that their correlation with the Continental arkose referred to cannot be supported on petrological grounds. In 1894 Mr. Clement Reid pointed out that towards Gorran Haven "shore conglomerates, belonging probably to upper part of Lower Devonian, rest directly on Ordovician or still older rocks."[3]

Finally, the researches of Mr. Howard Fox on the Radiolarian cherts of West Cornwall, and the assistance he has received in their determination by Dr. Hinde, must be referred to. Mr. Fox has shown that not only are these organisms confined to the horizon of the pillow lavas, which indicates such a remarkable association with Lower Silurian horizons in the south of Scotland and elsewhere, but he has proved their existence throughout the Silurian sequence of West Cornwall. The fact, moreover, that the most patient search has failed to detect their presence in the Devonian strata has furnished additional evidence in support of the differentiation of those systems in this region. On the assumption that the Old Red Sandstone was deposited in great inland basins it is possible that the British Devonian rocks, being so closely adjacent to the Welsh lake basin, were laid down in a partially enclosed sea like the Mediterranean, from which the oceanic organisms might have been almost entirely excluded.

Summary and Conclusion.

The main conclusions may be epitomised as follows:—

1. The Lower Palæozoic divisions, including the Veryan, Portscatho, Falmouth, and Mylor groups, form a natural sequence.

2. The Upper Palæozoic, represented by the Manaccan Series, rests unconformably on the Lower Palæozoics, and its constituents have been largely derived from the Veryan and Portscatho groups.

3. The Veryan and Portscatho groups were consolidated and veined with quartz, prior to their denudation and incorporation in the Manaccan conglomerate.

[1] Geol. Mag., 1904, p. 403.
[2] Geol. Mag., 1904, p. 590.
[3] Summary of Progress of Geological Survey for 1904, pp. 22–23.

4. The Manaccan Series are repeated on the horizons of Probus and Grampound, from which they extend across the county to either coast.

5. The Manaccan Series represent the basement beds of the Lower Devonian, and the Lower Palæozoic groups include Lower Silurian of Caradoc age, but whether the succession is ascending or descending has not been definitely proved, although the evidence suggests a descending sequence.

Before concluding, it may be remarked that the facts, herein presented, involved such a complete change in the colouring and interpretation of the old geological maps that a special investigation of the evidence on which the conclusions are based was undertaken at the request of the Director by Mr. H. B. Woodward and Mr. Clement Reid. As the result of that investigation they were satisfied that the conglomerate was partly derived from the underlying Veryan and Portscatho Beds, and that those groups, together with the associated Falmouth and Mylor Series, are of Pre-Devonian age. The conclusions, therefore, which form the subject of this communication not only embody the opinions of the author, but command the support of his official superiors of the Geological Survey.

EXPLANATION OF PLATE XIV.

Sketch-map to illustrate the geology of the Manaccan district.

IV.—Fossil Echinoidea from Sinai and Egypt.

By J. W. Gregory, D.Sc., F.R.S., F.G.S.,
Professor of Geology, Glasgow University.

(PLATES X and XI.[1])

THE collections of Echinoidea described in the following report were made by Messrs. Barron, Beadnell, and Hume during their work for the Egyptian Geological Survey, and were entrusted to me for description by the Director, Captain Lyons, R.E.

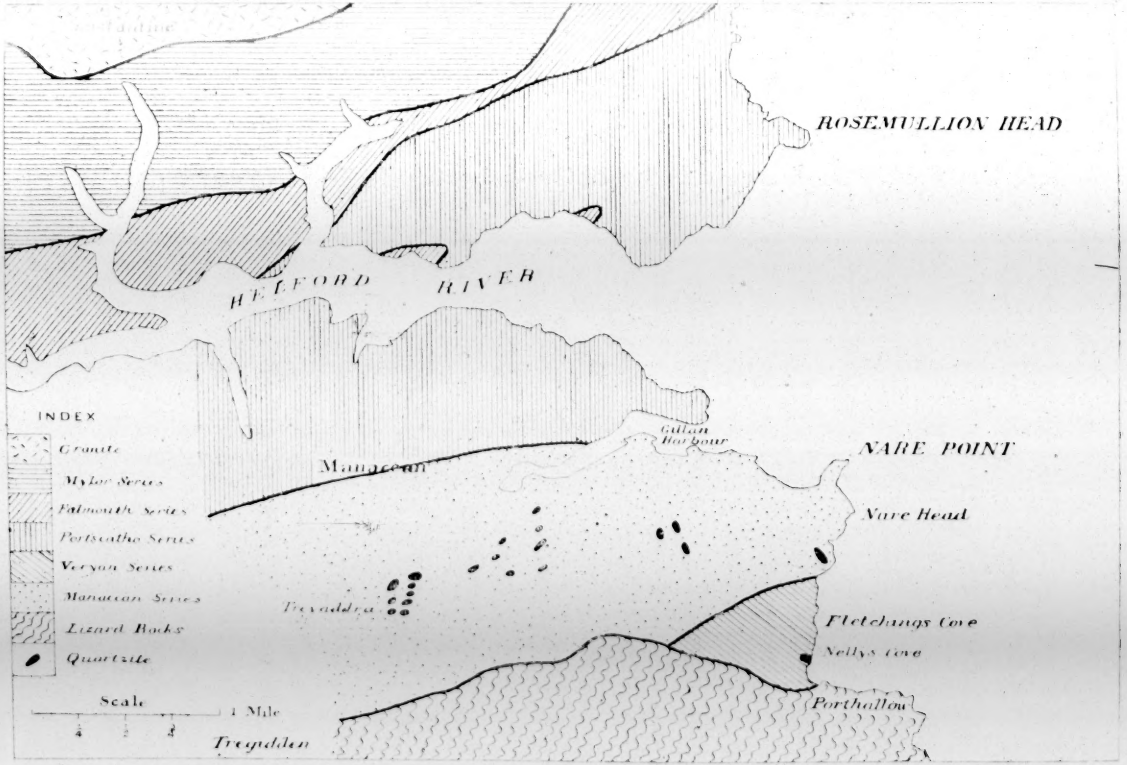
The collections belong to three main series—(1) Cretaceous, (2) Eocene and Miocene, and (3) Pleistocene. The Cretaceous Echinoids come from the massif of Abu Roash, and from Sinai. The specimens from Abu Roash were collected by Mr. H. J. L. Beadnell, and mostly came from the eastern end of the massif near the village of Abu Roash. The best known fossil from this horizon is *Coptosoma abbatei* (Gauth.), and the bed from which it comes has been assigned to both the Cenomanian and the Turonian. The sections published by Fourtau[2] show that the beds belong to the older part of the Cretaceous massif of Abu Roash; but he places the *C. abbatei* beds in the Turonian[3] or Lower Senonian.[4] Walther,

[1] [Plate XI will appear with the second part of Professor Gregory's paper in the June Number of the Geological Magazine.—Editor.]

[2] Fourtau: Notes E'ch. foss. E'gypte, 1900, p. 17.

[3] Fourtau: ibid., p. 21; and Crét. massif Abu Roash, C.R., vol. cxxxi (1900).

[4] Fourtau, Révision E'ch. foss. E'gypte: Mém. Inst. E'gypt., vol. iii, fasc. 8 (1899), pp. 607, 623.



Geological Sketch-map of the district bordering the Helford Basin.

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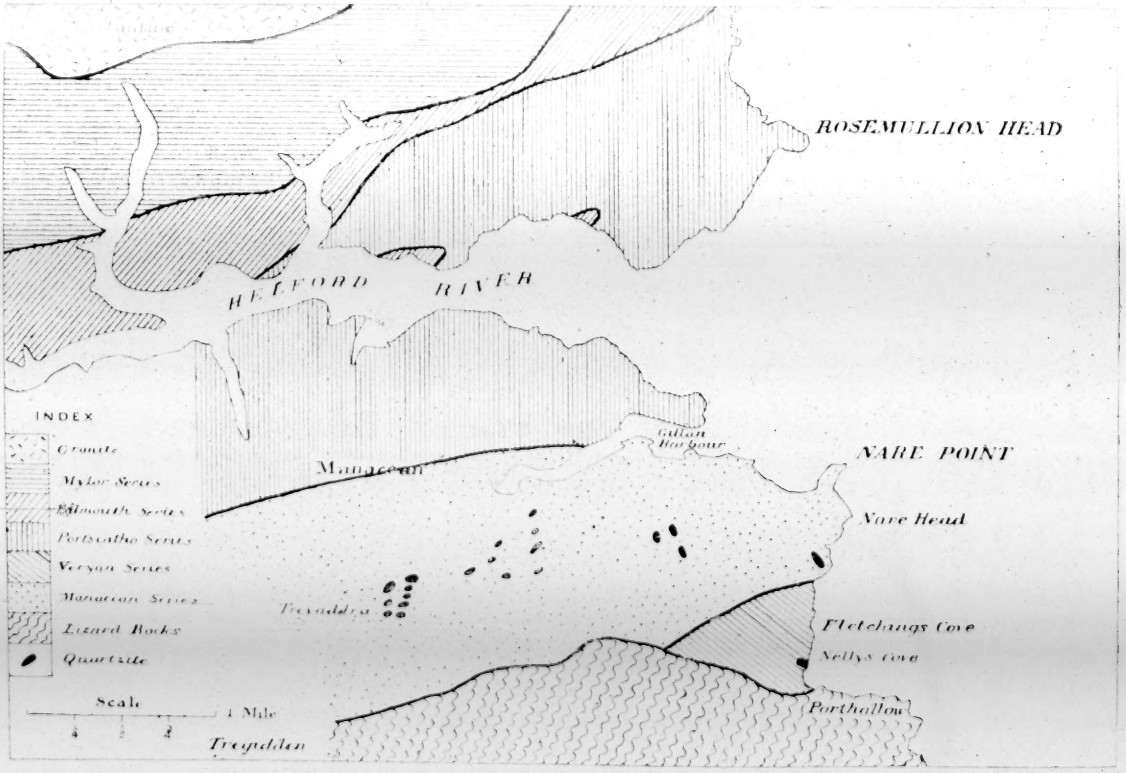


Geological Sketch-map of the district bordering the Helford Basin.

Schweinfurth, Blanckenhorn,[1] and Beadnell,[2] on the other hand, place these beds in the Cenomanian; so also does Dacqué.[3] But the Echinoids from these beds appear to me to be Turonian rather than Cenomanian. The Echinoids from this massif are few in number, and they are mostly species new to the locality, so that their evidence is by no means decisive. But the affinities of the Abu Roash Echinoids known to me are Turonian. The collections give no evidence of the occurrence of a Cenomanian Echinoid fauna at Abu Roash. Of course, Cenomanian beds may occur, from which Echinoids were not collected.

In Sinai, on the other hand, the bulk of Echinoids are of Cenomanian affinities, as shown in the table of species (*infra*). The Sinai Echinoids include two Turonian species and a new species, of which the nearest ally known to me is Turonian. This fact may represent either that the species lived in both epochs or that the beds of the two series occur at the same localities in Sinai.

The Cainozoic fauna in this collection, excluding the Pleistocene, is very small, and the specimens are not well preserved. The most puzzling form is an *Echinolampas* allied to *E. crameri*, Lor., which is reported as having been found in the raised beaches of Wadi Feiran; it is quite unlike any living *Echinolampas*. Professor Jeffery Bell, the best British authority on recent Echinoids, kindly examined the specimens, and tells me that they are unlike any living species. The affinities of these species are Miocene or earlier; possibly they were derived from blocks of limestone that may have fallen from an old cliff into a recent beach.

The Pleistocene fauna from both shores of the Gulf of Suez has purely Erythrean characters. Most of the specimens are identical with living species. A few specimens, however, which are badly preserved, may be of an earlier age, as they may be either recent or extinct species. All the well-preserved material is identical with the existing Red Sea species. There is nothing to suggest any considerable antiquity for these raised beaches. Seven specimens are somewhat doubtful, and two of them may be Pliocene or Miocene. Nos. K 1660 and J 1624 are both imperfect specimens, and cannot be identified; and K 1660 from the level of 380 feet in the Wadi Abu Shigeli is perhaps *Brissus egyptiacus*, Gauthier, which is assigned by its author[4] to the Miocene.

The three specimens referred doubtfully to *Schizaster gibberulus* are so imperfect that the determination is of no value. They may be crushed casts of that species, but their generic characters are not known.

The *Echinodiscus* is quite unlike any Pleistocene species, and the fragment of the *Clypeaster* (L 4204) described as coming from the

[1] Max Blanckenhorn, Neues zur Geol. & Pal. Aegyptens: Zeit. deut. Geol. Ges., 1900, p. 33.

[2] Beadnell, Cret. Reg. Abu Roash: Rep. Geol. Surv. Egypt, 1900, pt. ii (1902), pp. 18, 19, 20, etc.

[3] Dacqué, Mitth. Kreidecomplex Abu Roash: Palæontogr., vol. xxx (1903), p. 354.

[4] Fourtau, Révision Ech. foss. E'gypte: Mém. Inst. E'gypt., vol. iii, fasc. 8 (1899), p. 718, pl. iii, figs. 11, 12.

beach deposits of Wadi Feiran may be a fragment of a Miocene species. The only species from that locality which is satisfactorily determinable is an *Echinolampas*, which is a Lower Cainozoic or Miocene species. Hence it may be that the three species of Echinoids from the beach deposits of Wadi Feiran are *remanié* from a Miocene or Lower Cainozoic horizon.

I must express my best thanks to Captain Lyons for having allowed me to keep the collection so long, in spite of the unavoidable delays in the preparation of a report upon it.

I. CRETACEOUS.

Subclass *REGULARIA ECTOBRANCHIATA.*

Suborder *DIADEMINA.*

Family DIADEMATIDÆ.

HETERODIADEMA, Cotteau, 1864.

HETERODIADEMA BIGRANULATUM,[1] n.sp. (Pl. X, Figs. 1*a–f*.)

Diagnosis.—Test small, low; well flattened above and below; the ambitus is tumid.

Apical area large, its length is half the diameter of the test; and the ratio of breadth to length is 7 to 9 (it is 21 : 29 in *H. libycum*). In shape it is nearly pentagonal; the three anterior sides are straight, while the two posterior sides are somewhat convex. Peristome small.

Ambulacra, 13–14 compound plates in each vertical series; the passage from the large tubercles on the ambitus, to the smaller ones near the apex, is less sudden than in *H. libycum*.

Interambulacra, 10 compound plates in each vertical series; the scrobicular areas are not confluent, but occasionally the scrobicular circles become very thin, and the granules somewhat scanty; there are two granules in each of the horizontal rows (instead of the four in *H. libycum*) between the base of the boss and the median suture.

Dimensions:

Diameter	21 mm.
Height	8·5 mm.
Width of apical area	9 ,,
Length of apical area	11 ,,
Width of ambulacrum at ambitus	5·5 ,,
Width of interambulacrum at ambitus	8 ,,

Distribution.—Cenomanian: southern slope of Jebel Gunneh, Sinai. L 3506. Collected by Dr. W. F. Hume, 1899.

Figures.—Pl. X, Fig. 1*a*, from above, nat. size; Fig. 1*b*, from the side, nat. size; Fig. 1*c*, a compound ambulacral plate showing the granulation, by 4 diam.; Fig. 1*d*, a worn ambulacral plate showing the sutures, by 4 diam.; Fig. 1*e*, interambulacral plates showing

[1] From its double rows of granules around the bases of the ambital interambulacral tubercles.

the ornamentation, by 4 diam. ; Fig. 2, *Heterodiadema libycum* (Desor), two interambulacral plates, after Cotteau.

Affinities.—This echinoid is a typical *Heterodiadema* ; it differs from *H. libycum* (Desor),[1] the well-known type-species, by its non-confluent scrobicular areas, and by having only two instead of four granules in each row on the interambulacral plates.

Family DIPLOPODIIDÆ.

ACANTHECHINOPSIS,[2] n.gen.

Diagnosis.—Diplopodiidæ with the ambulacra diplopodous abactinally, where the plates are long, thin, simple primaries; but with uniserial epipodia on the actinal surface and near the mouth. The ambital plates are of five primaries, one of which may be reduced to a demiplate.

There is a bare depression in the median line of the abactinal part of the interambulacra.

Tubercles crenulate and perforate.

Type Species.—*A. humei*, n.sp.

Distribution.—Cretaceous : Sinai and Southern Tunis.

Affinities.—This species is most nearly allied to *Acanthechinus*, but it differs therefrom by its perforate tubercles.

ACANTHECHINOPSIS HUMEI, n.sp. (Pl. X, Figs. 3*a–e*.)

Test of medium size ; subpentagonal ; flat below, somewhat turban-shaped when seen from the side.

Ambulacra broad above, where the epipodia occur in long narrow primaries. The ambital plates have five primaries, one of which may be reduced to a demiplate, by being just crushed out from the middle line.

Interambulacra, about 16 plates in a vertical series. The tubercles begin as a single series, separated from the series on the opposite side of the interambulacrum by a bare depressed area. On the seventh plate from the top a second line of tubercles begins, and the ambital plates have three rows of tubercles in a somewhat oblique series.

Dimensions :

Diameter	36 mm.
Height	15 mm.
Diameter of peristome	12·5 mm.

Distribution. — Cenomanian : southern slope of Jebel Gunneh, Sinai. L 3506. Collected by Dr. W. F. Hume.

Figures.—Pl. X, Figs. 3*a* and *b*, test from above and from the side, nat. size ; Fig. 3*c*, ambulacral plates near the apex, by 4 diam. ; Fig. 3*d*, ambital ambulacral plates, by 4 diam. ; Fig. 3*e*, ambital interambulacral plates, by 4 diam.

[1] *Pseudodiadema libycum*, Desor, 1858 : Syn. E'ch. foss., p. 72. *Heterodiadema libycum*, Cotteau, 1864 : Pal. franç., Terr. crét., vol. vii, p. 522, pl. 1124. Cotteau, Peron, & Gauthier, 1879 : E'ch. foss. Algér., fasc. 5, p. 201, pl. xv, fig. 5. Gauthier, 1889 : E'ch. foss. S. Hauts-Plat. Tunisie, p. 68.

[2] Like *Acanthechinus*.

Affinities.—This species is most nearly allied to a specimen, described by Gauthier as *Diplopodia semamensis*, Gauth., from the Cenomanian of Jebel Semama in Southern Tunis, to which it is certainly a near relation. Gauthier referred to the abnormal characters of what he truly described as this "remarkable species." He had only one imperfect specimen; its dimensions are diam. 35 mm., height 12 mm., and diam. of peristome 11 mm.

A. humei differs from *A. semamensis* (Gauth.), as that has more abundant interambulacral tubercles.

	Acanthechinopsis humei.	*A. semamensis.*
Ambital plate has	a slightly oblique series of three tubercles.	a zigzag row of four tubercles.
The series of tubercles which begins at the top of interambulacral area	becomes the middle row at the ambitus.	remains the innermost line throughout.
The second vertical series of tubercles begin on the	fifth plate.	hird uppermost plate from top of 1*a*.
On the ambital plates	a large second tubercle appears inside the long row of primary tubercles.	no conspicuous secondary tubercle inside the main series.

Family PEDINIDÆ.

MICROPEDINA, Cotteau, 1867.

MICROPEDINA BIPATELLIS.[1] (Pl. X, Figs. 4, 5*a*–*f*.)

Test, the average size for this genus; well rounded, subspheroidal, but with depressed actinal surface, tumid ambitus, and the upper surface much more raised and tapering than the lower.

Circular in section.

Apical area and peristome both small.

Ambulacra: the epipodia appear conspicuously biserial, especially near the mouth, but at the ambitus they may be recognized as triserial.

The ambulacral plates on the ambitus consist of a large primary, with small adoral and aboral demiplates; the aboral and middle epipodia are in the same vertical line, near the interradius; the adoral epipodium occurs at about the middle of the lower edge, giving the biserial aspect to the ambulacrum.

Near the peristome the aboral plates may be a primary, and the adoral is nearly so. The ambital ambulacral plates are ornamented by two small granules. Interambulacra of long narrow plates with an irregular line of very small granules, which may be as many as seven in number. In some plates the line of granules becomes doubled near the ambulacrum.

[1] Having two small plates (or patella) in the compound ambulacral plates.

Dimensions :

	L 3482.	L 4323.	*M. olisipponensis.*	*M. cotteaui.*
Diameter	40 mm.	33 mm.	13–40 mm.	25 mm.
Height	28 mm.	26 mm.	...	22 mm.
Ratio of height to diam.	70 : 100	78 : 100	64 : 100 to 88 : 100	88 : 100

Distribution.—Egypt. Cenomanian : Jebel Gunneh (L 4323) ; northern side of Jebel um Raiyig, north-eastern Sinai (L 3482). Both collected by Dr. W. F. Hume.

Figures.—Pl. X, Fig. 4, a small specimen from the side, nat. size, from Jebel Gunneh, L 4323 ; Figs. *5a–f*, plates from L 3482 from Jebel um Raiyig ; Fig. *5a*, ambulacral plate from near the apical area, by 4 diam. ; Fig. *5b*, an ambulacral plate from the ambitus, by 4 diam. ; Fig. *5c*, an ambulacral plate from the actinal surface, by 4 diam. ; Fig. *5d*, an ambulacral plate from near the peristome ; Figs. *5e* and *5f*, ambital interambulacral plates, by 4 diam. Pl. XI, Fig. 15, the ambital ambulacral and interambulacral plates of *M. cotteaui*, Coq., after Cotteau.

Affinities.—The nearest ally of this species is *M. olisipponensis*, Lor.,[1] from the Cenomanian of Portugal, which differs by having three regular granules on the ambulacral plates, and somewhat larger granules on the interambulacrals. It differs from the type-species, *M. cotteaui*, Coquand,[2] by having an adoral demiplate, instead of both the lower plates in the ambital ambulacral plates being primaries. In this respect it resembles *M. olisipponensis*, which agrees with *M. cotteaui* in the granulation of both the ambulacral and interambulacral plates.

Family CYPHOSOMATIDÆ.

CYPHOSOMA, Agassiz.

CYPHOSOMA BEADNELLI, n.sp. (Pl. X, Figs. 6, *7a–d*, and 8.)

Diagnosis.—Test of medium size, subcircular and low.

Ambulacral plates composed of six constituents ; each plate has one large tubercle, and a median row of coarse scanty granules down the middle line of each area. The scrobicular circles are confluent. Interambulacra, 10 plates in a vertical series ; each bears one large tubercle, round the base of which is an incomplete scrobicular circle, a line of about 5 large granules on the inner and outer sides of the scrobicular circle, which is incomplete above and below in the ambital plates, so that the scrobicular areas are confluent.

Dimensions :

	Largest.	Another specimen.	Another specimen (Fig. *6*).
Diam. max. ...	28 mm.	23·5 mm. ...	24 mm.
Diam. min. ...	26 mm.	22 mm. ...	—
Height	9·5 mm.	7 mm. ...	10 mm.

[1] P. de Loriol : Crét. Fauna Portugal, vol. ii (1887), Echinodermes, p. 62, pl. x, figs. 3–6.

[2] Cotteau : Pal. franç., Terr. crét., vol. vii (1867), p. 823, pl. 1197.

Figures.—Pl. X, Fig. 6, abactinal view of a specimen, nat. size; Fig. 7*a*, another specimen from the side, nat. size: Fig. 7*b*, abactinal end of an ambulacrum of the same, by 4 diam.; Fig. 7*c*, an ambital ambulacral plate of the same, by 4 diam.; Fig. 7*d*, interambulacral ambital plates of the same specimen, by 4 diam.; Fig. 8, actinal surface of another specimen, nat. size.

Distribution.—Cretaceous (Cenomanian or Turonian): east end of Abu Roash village. L 1376. Collected by H. J. L. Beadnell, Esq.

Affinities.—The species is allied to the Turonian *Cyphosoma coquandi*, Cott.,[1] of Batna, Algeria, in which the granulation is more abundant, the scrobicular areas are not confluent, and there are only five components in the compound, ambital, ambulacral plates.

THYLECHINUS, Pomel, 1883.

1. Thylechinus quincuncialis,[2] n.sp. (Pl. XI, Figs. 8*a–c*.)

Diagnosis.—Test above medium size; circular; depressed.

Peristome moderate in size; circular with well-developed buccal slits.

Ambulacra: about 16 compound plates in each vertical series. The scrobicular circles are very incomplete; they may be represented only by a series of granules round the edge of the boss, but there may be a line above and below the boss, along the horizontal edge of the plate.

Interambulacra: about 13 plates in each vertical series. The plates are slightly bent, the abactinal margin being concave. The ambital tubercles are quincuncial in arrangement, and there are three vertical series on each side of an interambulacrum at the ambitus. The three plates nearest the peristome have one tubercle each.

Dimensions:

Diameter	30–31 mm.
Height	12–13 mm.

Distribution.—Cenomanian: Sinai, marls at the head of Wadi Ethal. L 3872. Collected by the late T. Barron, Esq.

Figures.—Pl. XI, Fig. 8*a*, a specimen from the side, nat. size; Fig. 8*b*, part of the ambitus, showing the plan of the interambulacral tubercles, by 3 diam.; Fig. 8*c*, two compound ambulacral plates from the same, by 4 diam.

Affinities.—This species resembles by its quincuncial tubercles one of the two echinoids included by Gauthier[3] in *T. sancti-arromani* (Gauth.), from the Dordonian (Upper Senonian) of Bir Maguer, Southern Tunis. It appears to me probable that the specimen illustrated by Gauthier's figs. 9–11 is a distinct species from his figs. 8, 12, and 13, which may be selected as the type of the species. This *Thylechinus quincuncialis* differs from *T. sancti-arromani* by the presence of only one tubercle, instead of a row of smaller ones on the plates next the peristome.

[1] Cotteau: Pal. franç., Terr. crét. (1864), p. 587, pl. 1139, figs. 7–12.

[2] From the plan of the tuberculation.

[3] *Cyphosoma sancti-arromani*, Gauthier, 1889: Ech. foss. Sud Hauts-Plateaux Tunisie, pp. 81–82, pl. v, figs. 8, 12, 13, *non* figs. 9–11.

2. THYLECHINUS TRIGRANULATUS, n.sp. (Pl. XI, Figs. 9*a–d*.)

Test low and small; circular; it is flat below, is tumid at the ambitus, and somewhat pointed above. Apical area small. Peristome decagonal, with broad buccal slits.

Ambulacra, about 11 compound and 5 abactinal primary plates, in a vertical series. The uppermost, or the two uppermost, compound plates are smooth, and have only a low granule. Each ambital plate has a single prominent tubercle, but little smaller than those of the interambulacra. The boss occupies nearly the whole of the non-poriferous part of the plate, and is surrounded by a thin single row of small granules on its border.

Interambulacra.—There are about 11 plates in each vertical series. The plates are long and low; the abactinal side is slightly concave. The base of the tubercle is surrounded by a circle of low granules, so that the scrobicular areas are non-confluent. Each plate typically has three prominent granules, one in each of the two adambulacral corners and one on the abactinal interradial corner.

Dimensions:

Diameter	22 mm.
Height	9 mm.
Diameter of apical area	5–6 mm.
Diameter of peristome	8–9 mm.
Width of ambulacrum at ambitus	5 mm.
Width of interambulacrum at ambitus	8·5 mm.

Figures.—Pl. XI, Fig. 9*a*, test from below, nat. size; Fig. 9*b*, from the side, nat. size; 9*c*, upper part of an ambulacrum showing the structure of the plates, by 4 diam.; 9*d*, part of an interambulacrum at the ambitus, by 4 diam.

Distribution.—Cenomanian — Cretaceous Marls: head of Wadi Ethal, Sinai. L 3872. Collected by the late T. Barron, Esq., 1899.

This *Thylechinus* is represented by one specimen; it is somewhat distorted, but the characters are well shown. The ornamentation reminds me most of *Cyphosoma baylei*, Cott. (Pal. franç., Terr. crét., vol. vii (1864), pl. 1138, fig. 12), which, however, is a true *Cyphosoma*.

COPTOSOMA, Desor, 1858.

1. COPTOSOMA ABBATEI (Gauthier), 1899.

Cyphosoma abbatei, Gauthier, in Fourtau, 1899: Rév. Ech. foss. Egypte, Mém. Inst. Egypt., vol. iii, fasc. 8, p. 620, pl. i, figs. 2–6.
Cyphosoma abbatei, Fourtau, 1900: Notes Ech. foss. Egypte, p. 21.
Cyphosoma abbatei, Dacqué, 1903: Mitth. Kreidecomplex Abu Roash, Palæontogr., vol. xxx, p. 357.
Pseudodiadema, sp., Walther, 1887: Apparition craie, Bull. Inst. Egypt., 1887, p. 7.

This species, well described by Gauthier, is represented by a good series of specimens. They show that the ambulacra are not diplopodous abactinally, so the species is a *Coptosoma*.

Distribution.—Cenomanian or Turonian: eastern end of the village of Abu Roash. I 3792. Collected by H. J. L. Beadnell, Esq.

2. Coptosoma gunnehensis,[1] n.sp. (Pl. XI, Figs. 10*a–d*.)

Diagnosis.—Test of medium size; subpentagonal in form. Flat base; somewhat tapering below. The middle area of the interambulacra is depressed near the apical system.

Apical system apparently somewhat small, pentagonal.

Peristome large, subdecagonal, with broad buccal slits.

Ambulacra: 13 compound plates each with one well-developed tubercle. Scrobicular circles confluent; a well-developed double series of granules down the middle line of each area. Four constituents in each ambital ambulacral plate.

Interambulacra: 12–13 plates in each vertical series. At the ambitus each plate bears two well-developed tubercles; the plates are bent into a step-like form, the central tubercles being half the width of the plate nearer the actinal surface.

Granulation scanty; the two scrobicular areas of each plate are confluent, but they are not confluent with those of the plates above and below it; usually two granules on the side of the plate near the ambulacrum.

Dimensions:

Diameter	27 mm.
Height	8 mm.
Diameter of apical area	9–13 mm.
Diameter of peristome	13 mm.
Width of ambulacrum at ambitus	5·5 mm.
Width of interambulacrum at ambitus	11 mm.

Distribution.—Cenomanian (?): Jebel Gunneh, Sinai. L 3506. Collected by Dr. W. F. Hume.

Figures.—Pl. XI, Fig. 10*a*, type-specimen from above, and Fig. 10*b*, from the side, nat. size; Fig. 10*c*, a compound ambital ambulacral plate, by 4 diam.; Fig. 10*d*, ambital interambulacral plates, by 4 diam.

Affinities.—This well-marked form has the doubly-bent, step-shaped, interambulacral plates found in various Cyphosomoid echinoids of the Middle and Upper Cretaceous, as in *Cyphosoma alcantarense*, de Loriol.[2] Its nearest ally is the Turonian *Coptosoma major* (Coquand),[3] which has a more granulate test, the two scrobicular areas on each plate being separated by a line of granules, and according to Cotteau's figures[4] the ambulacral plates consist of five primaries. Gauthier[5] included in his *Cyphosoma sancti-arromani* a specimen shown in his figures 9, 10, and 11, which is another ally of this species; it has the step-shaped interambulacral plates, but the secondary tubercles are on a somewhat different plan. *C. sancti-arromani* is from the Dordonian (i.e. Maastrichtian or uppermost Senonian) of Southern Tunis.

[1] From Jebel Gunneh, the locality of the type-specimen.

[2] P. de Loriol: Faune Crét. Portugal, vol. ii (1887). Echinod., p. 52, pl. ix, fig. 4, from Up. Carentonian.

[3] *Phymosoma major*, Coquand, 1863: Géol. et Pal. Constantine, Mém. Soc. Emul. Provence, vol. ii, p. 256, pl. xxvii, figs. 16, 17.

[4] Cotteau: Pal. franç., Terr. crét., vol. vii (1864), pl. 1143, fig. 5.

[5] Gauthier: Ech. foss. Sud Hauts-Plateaux Tunisie, pl. v, figs. 9–11, *non* figs. 8, 12, 13.

Subclass *IRREGULARIA*.

Order 1. GNATHOSTOMATA.

Suborder *HOLECTYPINA*.

Family PYGASTERIDÆ.

HOLECTYPUS.

1. Holectypus cenomanensis, Guéranger, 1859.

Holectypus cenomanensis, Guéranger, in Cotteau & Triger: E'ch. Dep. Sarthe (1859), p. 173, pl. xxx, figs. 5–10.
Holectypus cenomanensis, Duncan, 1865: Ech. Coast Arabia, Quart. Journ. Geol. Soc., vol. xxi, p. 354.
Holectypus cenomanensis, Fourtau, 1899: Rév. E'ch. foss. E'gypte, Mém. Inst. E'gypt., vol. iii, fasc. 8, p. 625.

Distribution. — Cenomanian: Algeria, France, etc.; Jebel um Raiyig, north-eastern Sinai. L 3483. Collected by Dr. W. F. Hume. Cretaceous Marls: Jebel el Araba, Wadi el Araba, Sinai. L 4220. Collected by the late T. Barron, Esq.

Dimensions:

	L 3483.	L 4220.	*jullieni*.	*cenomanensis*.
Diameter ...	— ...	— ...	24 mm. ...	45 mm.
Length	40·5 mm. ...	22·5 mm. ...	35 mm. ..	31 mm.
Width	39 mm. ...	22·25 mm. ...	11 mm. ...	31 mm.
Height	21 mm. ...	10 mm. ...	15 mm. ...	15 mm.
Length to width...	100 : 96·3 ...	— ...	— ...	100 : 48·4
Length to height...	100 : 51·8 ...	— ...	100 : 45 to 42·8 ...	Diam. in this species is up to 45 mm.[1]

Affinities.—The characteristics of this species are its comparatively large size (up to 45 mm. in diam.), the subpentagonal or subcircular form, the very low, conical form, and the great size of the periproct, which is acuminate at both ends, and extends from the peristome to the margin.

It differs from the *Echinoconus egyptiacus*, d'Orb.,[2] by its low height; from *H. excisus*, Cott.,[3] by the fact that the periproct does not notch the posterior margin of the test. *H. serialis*, Deshayes,[4] is much smaller, and has less numerous tubercles on the interambulacral plates; and so also has *H. jullieni*, P. & G.[5] The latter is a Turonian and Senonian species, and in spite of its somewhat lower height is a near ally of *H. cenomanensis*.

2. Holectypus turonensis (Desor), 1847.

In Agassiz & Desor: Cat. rais., Ann. Sci. nat., ser. III, vol. vii, p. 146.
Cotteau: Pal. franç., Terr. crét., vol. vii (1861), p. 56, pl. 1018.
Cotteau, Peron, & Gauthier: E'ch. foss. Algér., fasc. 6 (1879), p. 87.

[1] Cotteau, Peron, & Gauthier: E'ch. foss. Algér., fasc. 5 (1879), p. 172.
[2] D'Orbigny: Pal. franç., Terr. crét., vol. vi, p. 544, pl. 1005, figs. 7–9.
[3] See e.g. the figure in Cotteau & Triger: E'ch. Dep. Sarthe, p. 368, pl. lxii, figs. 1, 3.
[4] See Desor: Syn. E'ch. foss., p. 174, pl. xxiii, figs. 6–9.
[5] Peron & Gauthier: E'ch. foss. Algér., fasc. 6 (1880), p. 85, pl. vi, figs. 3–7; fasc. 7 (1881), p. 91.

Distribution. — Turonian : S. France, and Tebessa, Algeria. ? Cenomanian—Cretaceous Marls : Sinai, Wadi Ragga (L 4123); and head of Wadi Ethal (J 3873).

This species is represented by three specimens, of which the two from the Wadi Ragga show all the characters very well. They resemble the Cenomanian *H. crassus*, of which it is possible that they are young specimens.

Their dimensions are :—

	J 4233.	*H. crassus*, *fide* Cotteau.
Diameter	15–23 mm.	... 51½ mm. by 31 mm.
Height	7–10 mm.	... 17 mm.

The ornamentation and shape agree with *H. turonensis* better than with *H. crassus*. The periproct notches the hinder margin, as much as in the French specimens, whereas the Algerian specimens are said by Cotteau, Peron, & Gauthier (op. cit., p. 88) only rarely to do so.

3. Holectypus larteti (Cotteau), 1867.[1]

Cotteau, Notice Ech. foss. recueillis par Lartet pendant voyage duc de Luynes: Bull. Soc. géol. France, ser. II, vol. xxvi (1869), p. 537.
Lartet: Explor. géol. Mer Morte, Paris (1877), p. 155, pl. xiv, figs. 1–5.

Distribution.—Cretaceous: Mt. Hor (coll. Lartet). Cretaceous Marls : head of Wadi Ethal, Sinai. L 3873. Coll. T. Barron, Esq.

This species, by its small periproct, has some resemblance to *Discoidea*, but the peristome is typically that of *Holectypus*. The largest of the three specimens is 23 mm. in diam., and 12·25 mm. in height.

According to Lartet's figure the diameter of the type-specimen is 25 mm. and its height 13 mm. The nearest Algerian species is *Holectypus chauveneti*, P. & G.,[2] in which the diameter and height are 18 mm. and 8 mm. respectively.

Family GALERITIDÆ.

GALERITES, Lamarck.

Galerites thomasi (Peron & Gauthier), 1878.

Echinoconus thomasi, Peron & Gauthier, 1878 : Ech. foss. Algér., fasc. 5, p. 162.

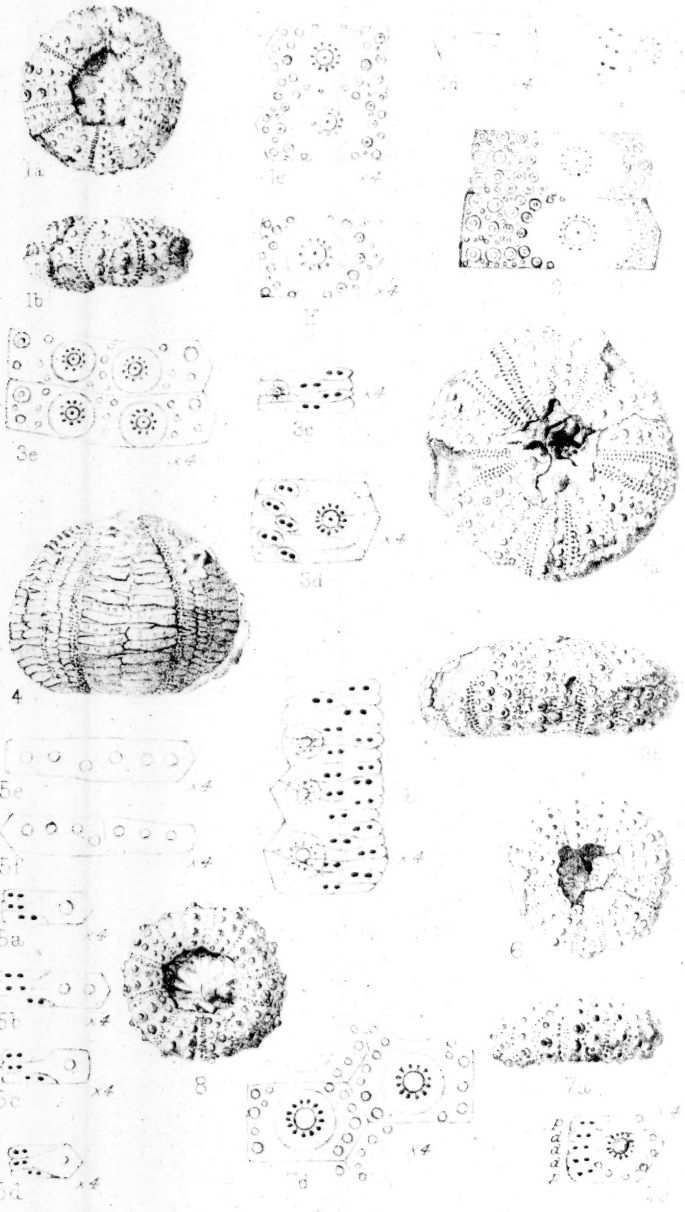
Distribution.—Cenomanian: Algeria (Berouaguiah); head of Wadi Ethal, Sinai. ? L 3873. Coll. T. Barron, Esq.

This species was founded on a very imperfect specimen which showed neither periproct nor peristome, so that the identification is doubtful.

L 3873 includes only one imperfect, worn specimen, which has the tumid margin, a slight actinal flattering, a large subpentagonal peristome, which is large for this genus, and a submarginal periproct.

The apical system agrees with that of *Galerites thomasi*.

[1] Compt. Rend., vol. lxxviii (1867), p. 198.
[2] Peron & Gauthier: Ech. foss. Algér., fasc. 5, p. 172, pl. xii, figs. 3–6.



E. Drake del. et lith. West, Newman imp.

Fossil Echinoidea from Sinai & Egypt.

EXPLANATION OF PLATE X.

FIG. 1.—*Heterodiadema higranulatum*, n.sp. Cenomanian: south slope of Jebel Gunneh, Sinai. L 3506. Collected by Dr. W. F. Hume.
1*a*, type-specimen from above. Nat. size.
1*b*, from the side. Nat. size.
1*c*, a compound ambulacral plate showing the granulation. × 4 diam.
1*d*, part of a worn ambulacral plate, showing the structure of the compound plates. × 4 diam.
1*e*, two interambulacral plates, showing the ornamentation. × 4 diam.
1*f*, another interambulacral plate. × 4 diam.
FIG. 2.—*H. libycum* (Desor). Interambulacral plates after Cotteau.
FIG. 3.—*Acanthechinopsis barroni*, n.sp. South slope of Jebel Gunneh, Sinai. L 3506. Collected by Dr. W. F. Hume.
3*a*, *b*, the test from above and from the side. Nat. size.
3*c*, ambulacral plates near the apex. × 4 diam.
3*d*, ambital ambulacral plates. × 4 diam.
3*e*, ambital interambulacral plates. × 4 diam.
FIGS. 4–5.—*Micropedina bipatellis*, n.sp. Cenomanian: Sinai. Collected by Dr. W. F. Hume.
4, a small specimen from the side. Nat. size. Jebel Gunneh. L 4323.
5*a–d*, ambulacral plates from L 3482. × 4 diam.
5*a*, a plate near the apical area.
5*b*, a plate from the ambitus.
5*c*, a plate from the actinal surface.
5*d*, a plate near the peristome.
5*e*, *f*, ambital interambulacral plates from L 3482. × 4 diam.
FIGS. 6–8.—*Cyphosoma beadnelli*, n.sp. Cenomanian or Turonian: east end of Abu Roash. Collected by H. J. Beadnell, Esq.
6, abactinal view of a specimen. Nat. size.
7*a*, another specimen from the side. Nat. size.
7*b*, abactinal end of an ambulacrum of the same. × 4 diam.
7*c*, ambital ambulacral plate of the same. × 4 diam.
7*d*, interambulacral ambital plates of the same specimen. × 4 diam.
8, actinal surface of another specimen. Nat. size.

(*To be concluded in the June Number.*)

V. — NOTES ON THE CORRIES OF THE COMERAGH MOUNTAINS, CO. WATERFORD.

By F. R. COWPER REED, M.A., F.G.S.

(*Concluded from the April Number, p.* 161.)

BETWEEN Crotty's Lough and Coumshingaun a long spur of the Comeraghs juts out eastwards for about a mile and a half with an average height of 1400–1500 feet. On the south side this projecting ridge descends rather steeply to a stream at its base, which heads at a height of over 2,400 feet on the lofty plateau between Coumgorra and Coumshingaun; it runs down the mountain-side in a narrow gully over bare rock and reaches the foot in a series of picturesque waterfalls. No glacial débris occurs in this ravine, but on the lower ground the stream flows over the margin of the moraines belonging to Coumshingaun and runs eastward as the River Ire to join ultimately the Clodiagh.

We now come to *Coumshingaun*, the principal and best known corrie in the Comeraghs and containing the largest lake. The corrie has the form of a somewhat elongated horseshoe and faces

west. It is situated only about one-third of a mile south of Crotty's Lough, with the above described ravine of the River Ire between them. The mouth of the corrie measures about 500–600 yards across, being narrowed by the approach of the enclosing spurs, but towards its head it expands considerably, so that the opposing cliffs are as much as 1,100 yards apart, measured from edge to edge. The lower half of the cliff at the head is composed of two successive precipices, which descend almost vertically to the water's edge and correspond to massive rock-beds. There is only a small talus slope as the foot, and above the main precipices the cliff is composed of the straight edges of many thinner beds of sandstone, which form a series of small scars and ledges on which rest small grassy talus slopes. The total height of this cliff in one place amounts to 1,288 feet in a horizontal distance of 400 yards, giving a mean slope of 46½° (Geol. Surv. Mem., p. 6). To anyone standing at the mouth of the corrie and looking west the cliffs appear nearly perpendicular, and

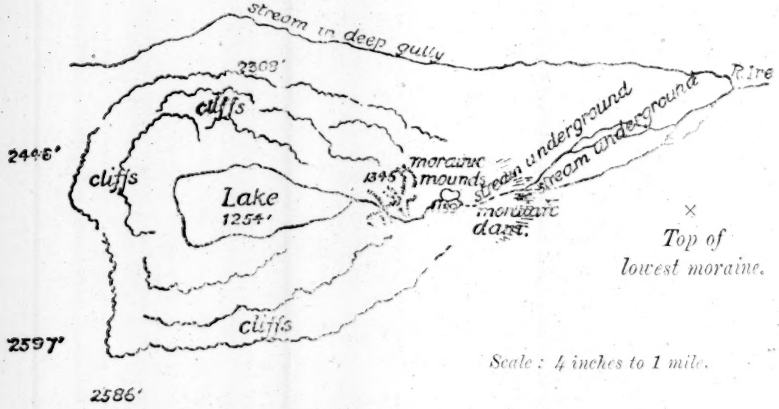


Fig. 6.—Sketch-map of Coumshingaun and Lake.

the beds, whose truncated edges form them, are seen to have a slight dip to the south. The north and south sides of the corrie are only precipitous in their middle or upper parts, all their lower half being covered with steeply inclined grassy screes. The spur on the southern side is prolonged eastwards as a narrow ridge with regularly sloping sides, and has the typical appearance of a valley-side plastered with lateral moraine. The northern spur is shorter and rounded more abruptly, and the solid rock crops out in many places on its surface.

The level of the lake itself is 1,254 feet above the sea, and a small clear stream issues from its southern corner close under the southern spur and finally joins the River Ire after a course of about two miles. The lake is of an elongated oval shape, with its longer axis running the length of the corrie and measuring about 750 yards; its breadth near the middle is about 300 yards, and it practically covers the

whole floor of the corrie from one precipice to the other with no level ground round its edges. The eastern end of the lake is obviously shallow, but local report credits the middle with being of great or even unfathomable depth. No accurate soundings are, however, on record, so far as I know.

The existence of morainic dams across the mouth of the cwm is strikingly apparent to any casual observer, and on ascending from the level of the high road up to the lake three distinct transverse moraines may be recognised. The lowest has a steep but irregular face, and its surface forms a more or less level broad shelf, across which meander many small streams. Huge angular masses of rock and more or less rounded boulders are scattered over it, and several examples of perched blocks—all of red sandstone or conglomerate—are noticeable. At a level of about 800 feet there is another and well-marked step in the slope, which indicates that we have reached the face of the second moraine. The face is steep and rough, and many springs issue from its foot or at various levels on the slope. We then cross its somewhat irregular surface, which is of less width than the lower one, and as we draw near the lake meet with a series of large and overlapping mounds of morainic material and irregularly distributed large boulders, which form the final barrier and dam to the waters of the lake. The maximum height of these mounds is about 100 feet above the level of the water. The stream which issues from the lake runs between them near the southern spur of the mountain, and expands into several small pools before descending the steeper slopes of the moraines or soaking through them to reappear as springs at a lower level. Its course at first is certainly not over solid rock, and it is clear that the mouth of the corrie is at any rate to a large extent filled up with drift. Its resemblance to a 'hanging valley' is well seen from the opposite slopes of Croghaun Hill (Pl. XIII, Fig. 2).

South of Coumshingaun there is another large corrie in the face of the escarpment looking east and measuring about 850 yards in depth and 600 in width. Though possessing less striking surroundings than Coumshingaun and devoid of a lake on its floor it is essentially of the same character, and the mouth is similarly blocked with transverse moraines. The floor of it is almost entirely occupied with extensive screes which slope down from the cliffs around it and may have filled up a pre-existing lake. A stream issues from this corrie and flows in a south-easterly direction to join the River Mahon after a course of about 4 miles. There is no other definite corrie in this escarpment, but about 2½ miles to the west of it on the southern slopes of the mountains, and only separated from the great corrie of the Stilloges in the Nier Valley by a narrow ridge 300 yards wide and just 2,350 feet high, there is a wide shallow amphitheatre formed by a gently curved line of cliffs, about 750 yards long, beneath which lie two small lakelets, from which issues the Coum Tay stream joining the River Tay below.

We may now turn to the Nier Valley, which possesses some striking elongated corries or rather precipitously walled hanging

valleys on its south side. Standing on the Gap in the Comeragh Range between Knockanaffrin and Coumgorra, we look westwards down the Nier Valley and note that the Gap is in reality a low col at the head of the River Nier. On our left we observe several deep tributary valleys entering the main valley from the south, and their generally bare craggy sides and hanging mouths attract attention. The head-stream of the River Nier issues from such a valley immediately on our left, and this valley starts behind Coumgorra and has its mouth spanned by successive banks and mounds of coarse morainic material. It lies at a considerable height above the thalweg of the Nier Valley itself, as in the case of a typical hanging valley, and its sides are rocky and precipitous in places and glaciated close to the present stream (see Geol. Surv. Mem., Sheets 167, 168, etc., p. 80), which has cut a small gorge at the head of the valley in its descent from the summits above, which rise to a height of nearly 2,500 feet.

A long narrow spur, only about 250 yards wide, separates this interesting glen from the large amphitheatre containing the *Comeragh Loughs*. This elongated amphitheatre or short hanging valley appears to be a composite corrie like Coumgorra, and its wide mouth (measuring nearly three-quarters of a mile across) faces nearly due west. Its depth is only about 700 yards, and its sides are precipitous, the lofty cliffs reaching a height of over 700 feet. The mouth of this corrie is blocked in the usual manner by glacial mounds, and the two lakes which it contains are separated also by heaps of morainic material. The inner lake, which measures about 200 yards across, lies at an elevation of 1,650 feet, and the outer and lower one, which is of rather smaller size, at 1,537 feet. The stream which flows out of the inner one is joined by one from the lower one and then runs down to the Nier. No clear evidence of the existence of a true rock-basin is at present available.

The immense corrie or short rocky valley named *Coumstilloge*, which holds the Stilloge lakes at a level of about 1,700 feet above sea-level, is the next one down the Nier. It faces the north-west, with a mouth nearly a mile wide, and with a depth of just over a mile. It appears to be formed by the confluence of three simple corries, two of which seem to have become merged to compose the broad amphitheatre at its head which holds on the east side Loughs Coumstillogemore and Coumstillogebeg, which are in close proximity to each other and lie in line along the stream which runs down to the main valley. To the west of these tarns there lie in the smaller corrie of the head-pair three small unnamed tarns without any surface-outflow. The mass of Coumfea Mountain, 2,340 feet high, projects into the south-western side of the composite corrie and overhangs the third or lateral constituent corrie which holds Lough Couma beneath precipitous cliffs about 600 feet high. This tarn has also no visible outlet.

The minute features of this Stilloge Valley and its group of lakelets have not yet been thoroughly examined, but it appears that glacial dams and mounds have led to the formation of the lakelets,

and in general features of cross-section, hanging mouth, and precipitous walls it resembles Coumgorra and the other corries.

The difference between the north and south sides of the Nier Valley is striking, for corries or lateral valleys of the type described are conspicuously absent on the northern flanks.

Origin of the Corries.

In striving to find an explanation of the origin of these corries and lakes in the Comeragh Mountains we are met at the outset by the still unfinished controversy as to the method of formation of all corries and rock-basins. There are current the theories of glacial erosion, subaerial erosion, marine erosion, and tectonic movements.

Thoroughgoing glacialists, like the Rev. Maxwell Close,[1] have ascribed the carving out of the Irish corries themselves, as well as the hollowing out of their floor, to the unaided action of ice. Others believe that the main or preliminary processes in their formation were effected by the ordinary subaerial agencies, and consider that ice has only played a subordinate part, superinducing certain peculiar features by which we can distinguish true cirques from the funnel-like heads of ordinary valleys of erosion.[2] Others maintain that typical cirques occur even in mountain regions which we have no reason to believe were ever glaciated,[3] and that the origin of the corrie was to a large extent independent of and prior to the formation of the hollow holding the lake, whether the latter lies in a rock-basin or a barrier-basin.

Kinahan[4] has urged the primary importance of faults, joints, and local dislocations of the strata producing lines of weakness along which marine erosion has acted; and he compares the cwms to the 'cooses' on the Galway coast, the shape of which has been determined by the intersection of various small faults.

Finally, tectonic movements, causing local subsidences, have been considered sufficient to account for their features, which indeed recall those of calderas[5] and of the breached craters of Auvergne.[6]

The most acceptable theory seems to be that of a modified head of a valley of erosion. The head of an upland glen, be it short or long, tends to have a half funnel shape, owing to the convergence to a central point of the various streams descending its slopes; and, given certain favourable conditions,[7] such a valley head may be converted into a true cirque. One of these conditions is the moderate horizontality of the strata over which the streams fall. Another is that the rocks must be of such a nature as to allow the formation of cliffs, and for this purpose well-jointed bedded limestones or sandstones of considerable toughness and durability are especially

[1] Maxwell Close: Journ. Roy. Geol. Soc. Ireland, vol. ii (1871), p. 236.
[2] Richthofen: "Führer für Forschungreisende," 1886, pp. 255–259.
[3] James Geikie: "Great Ice Age," 3rd ed., 1894, p. 236.
[4] Kinahan: "Valleys and their Relations to Fissures, etc.," p. 126; London, 1875.
[5] Richthofen: op. cit., p. 255.
[6] Howorth: "Ice and Water," vol. i (1905), p. 535.
[7] Bonney: Quart. Journ. Geol. Soc., vol. xxvii (1871), pp. 312–324; ibid., vol. xxix (1873), pp. 382–398.

suitable. Major lines of weakness, such as faults, will also be favourable for the development of cliffs.

It is probable also that in the first instance some suitable configuration of the ground at the head of the glen must have existed, such as the presence of a bare rock-face, more or less vertical, which may have been caused by a landslip due to the bursting out of springs at or near the base of a steep terminal slope. A cliff under the above-mentioned conditions would tend to be preserved, and by eating its way backwards into the slope would increase in height and extent under the action of weathering, particularly of frost, as is the case in Norway. The aspect of such a cliff with respect to the four quarters of the compass would have also some effect in determining its preservation and growth; and the fact that the majority of corries face north or north-east, and are rare on the other slopes of mountains and on escarpments facing in other directions, has been noticed throughout Europe.[1] Their position has sheltered them from the moisture-laden winds from the south-west and from the consequent rapid denudation which takes place under their influence. If ice and snow have, moreover, played a considerable part in the development of the peculiar characters of corries, it is on the northern sides of mountains that ice and snow would linger longest.

If we regard cirques to be of the nature of valley-heads formed under special conditions we have not even then surmounted all the difficulties connected with them. For we still have to explain their shortness in proportion to their width, their flat or excavated floors, their U-shaped cross-section, their frequent horse-shoe shape, and their occurrence as niches or recesses high up on the lateral flanks of main valleys or on escarpments, with their floors nearly level or even hollowed out, and the ground from their mouths sloping down steeply to the base of the mountain-side. The problem is of the same essential character as that of 'hanging valleys,' and some geologists regard them as merely hanging valleys of a special type and with a special history. Their niche-like position has been accounted for by supposing the main valley to have been widened and over-deepened by ice or water, while erosion in the lateral valleys was checked. It has been contended by Professor Davis that the glacier of the main valley has ground out its channel, deepening it and widening it at the expense of the lower parts of the lateral valley, which were occupied by small glaciers joining the main glacier at the level to which its mass rose against the lateral slopes. The main ice-stream in this way passed transversely across the lower ends of these tributary valleys, planing them down and truncating them abruptly. The corries in Skye have been thus explained,[2] and the hanging valleys of the Rhone. But this theory meets with much opposition. In the case of the Alps a general post-glacial or inter-glacial uplift has been suggested, when the main valleys would tend to be rapidly excavated by

[1] Penck: Morphol. d. Erdoberfl., ii (1894), p. 310.
[2] Harker: Trans. Roy. Soc. Edinb., vol. xl, pt. 2 (1901), pp. 221–252.

torrential rivers arising from the rapid melting of the ice and snow, but the glaciers in the upper parts of the side valleys would still persist and protect their beds from erosion.[1] The result in either case would be the same; the heads of the lateral valleys would be left hung up above the main thalweg when the period of excessive erosion was ended. Such may have been the first stage in the evolution of the Comeragh corries. Any new descent of the snow-line on the return of colder conditions would cause the lateral glaciers to advance and lead to the accumulation of mounds or dams of glacial débris in or beyond the mouths of the lateral 'hanging valleys.'

It is not without significance that the vertical distribution of hanging valleys along the sides of a main valley has in certain instances been found to bear a definite relation to the thalweg. Similarly, in many districts corries have been observed to possess a certain uniformity of level; but this is held by some geologists to indicate a former snow-line. Successive tiers of corries in belts (which are not unknown in some regions) are accordingly regarded as marking successive stages in the retreat of the snow-line.[2]

In the Comeraghs there is only one belt or zone of corries recognisable, and this lies between the contour-lines of 1,250 and 1,500 feet. Carvill Lewis (op. cit.) noticed that these mountains were glaciated up to a height of about 1,000 feet, and we may perhaps imagine the mountain-mass above this level to have stood up as a nunatakkr above the great ice-sheet during the period of maximum glaciation.[3] A lobe of the ice may have forced its way over the low col by Coumgorra and descended the Nier Valley. The heads of the lateral valleys which were not invaded by the ice would be modified during this period by the action of frost; their rocky sides would be splintered into cliffs, helped by the bedding, lie, vertical divisional planes and character of the rocks.

When the maximum cold and the ice which swathed the lower hill-slopes departed, these rock-walled niches were found left as the sole representatives of the former lateral valleys. Some were short and wide, others were long and complex, their size and shape having been determined by the various local conditions which affected the flow, pressure, and height of the ice-stream which crossed their mouths. On the return of the cold, though in a less severe form, an ice-cap probably formed on the mountains[4] and sent tongues down into the incipient corries on its flanks. The corrie-glaciers thus originating would produce the modifications in the already formed hanging valley-heads which were needed to convert them into true cirques. The U-shaped cross-section which we notice in them is characteristic of glaciated valleys. The frequent widening towards their head, though begun before the formation of the corrie-glaciers, was increased by the scouring out of the accumulated

[1] Bonney: Q.J.G.S., vol. lviii (1902), pp. 590–701. Garwood: id., pp. 703–714.
[2] Penck: op. cit., pp. 307–309 and references.
[3] Maxwell Close: Journ. Roy. Geol. Soc. Ireland, vol. i (1867), p. 228.
[4] Hull: Phys. Geol. Geogr. Ireland, 1878, pp. 103, 263.

screes against their cliffs and of the débris on their floor. Ice-falls from the edge of the ice-cap would assist the radial recession of the cliffs at the head, and tend to develop a horse-shoe shape to the corrie. A concentration of the erosive energy of the glacier must be produced at some central point in the floor, and, in the opinion of many geologists, its effects would be apparent by the excavation of a rock-basin. Even Kinahan (op. cit., p. 131) admitted that ice could thus enlarge and deepen a corrie. But the controversy as to the power of a glacier to scoop out a basin in solid rock is still raging, though no other agent capable of producing hollows, such as those in which the Snowdon lakes lie,[1] has been discovered, and apart from ice-erosion we have to imagine special local subsidence. The fact that infra-glacial corrosion does take place under certain conditions in modern glaciers during their advance seems now indisputably established. But in the case of the Comeragh lakes it has not been definitely proved that any of them lie in true rock-basins, and in all which I have examined the morainic dams which stretch across the mouths of the corries seem sufficient to account for their existence. Detailed soundings are, however, not available at present, and we must not forget Marr's[2] warning as to the inconclusiveness of the evidence furnished by the nature of the surface over which the stream flows as it issues from the lake. The glacier occupying the corrie could scarcely fail to scour out and remove all the abundant débris in the shape of screes and loose material strewn on the floor, and would deposit them outside in successive heaps and dams of moraine. Stages and halts in the dwindling away of the glaciers and in the retreat of the snow-line while glacial conditions passed away are marked by the remains of such dams; and their present preservation is due to the weakness of the erosive power of the streams issuing from the corries or draining off the overflow of the lakes held up by them. The frost and snow of every winter splits off fragments from the unprotected face of the cliffs, and the jointing of the rocks tends to preserve their vertical character, while the growth of scree material at their foot is an index of their waste since the glacier departed.

EXPLANATION OF PLATE XIII.[3]

Fig. 1.—Mouth of Coumshingaun (Comeragh Mountains) from surface of lowest moraines, showing steep face of middle morainic dam.

Fig. 2.—Coumshingaun (Comeragh Mountains) from Croghaun Hill, showing the lower morainic slope strewn with boulders, and the steep-faced middle dam bearing irregular morainic mounds near edge of lake. Crotty's Rock on skyline near right margin of view.

Fig. 3.—Coumgorra (Comeragh Mountains), showing mouth of inner corrie, from top of lowest shelf of moraine. Outer amphitheatre on right of view.

[1] Jehu: Trans. Roy. Soc. Edinb., vol. xl, pt. 2, No. 20 (1902), pp. 419–467 and references.

[2] Marr: Q.J.G.S., vol. li (1895), p. 35; ibid., vol. lii (1896), p. 12.

[3] [This Plate appeared in the April Number with the first part of Mr. Cowper Reed's paper.—Edit. Geol. Mag.]

REVIEWS.

I.—Geological Survey of Canada. By Robert Bell, M.D., F.R.S., etc., Acting Director. Report on the Klondike Goldfields. By R. G. McConnell, B.A. Part B of Annual Report, vol. xiv. 8vo. Ottawa, 1905.

THIS report is based on field-work carried on during the season of 1903, and completes a preliminary report published in 1900.

The existence of gold on the Yukon has been known since 1869, first in Alaskan, afterwards in Canadian territory. The Klondike district came into notice in connection with gold-mining in the year 1894. The goldfields have an area of about 800 square miles, and are situated east of the Yukon River in latitude 60° North. The streams flowing through the area are all gold-bearing to some extent, but only a limited number have proved remunerative. The Klondike and Indian Rivers, bordering the district on the north and south respectively, are comparatively small streams; both drain into the Yukon. The smaller streams and creeks draining the interior of the district are the sources of the gold.

The geological features of the country may be summarized as follows:—The rocks have a wide range in age, and present great variations in structure and composition, owing to igneous intrusions at different periods and enormous pressure from earth-movements. The oldest and most important formations consist of ancient schists, partly of clastic, partly of igneous origin.

The schists are divided into three series, viz., the Nasina Series (clastic), the Klondike Series, and the Moosehide Series (diabase). The unaltered sedimentary rocks belong to Early Tertiary (Renai?) and Late Tertiary (Flat-creek Beds). The massive igneous rocks comprise granite, diabase, andesites, quartz porphyries, and serpentine. These rocks are fully described in the report.

A description of the gold-producing creeks with illustrative sections is given, showing the position of the auriferous gravels and their relations to the underlying 'Klondike schists.' The methods used for extracting the gold are either by sinking and drifting or by open-cut work. The gravels, being everywhere frozen, require to be thawed before they can be extracted, and this is done, except in remote districts, by means of steam thawers or by pumps. The gold production of the Yukon territory since the discovery of the Klondike goldfields in 1896 is estimated by the Geological Survey at over 96,000,000 dollars (1896–1903). Nearly the whole of this immense amount was obtained from the various Klondike creeks and benches.[1] It is stated that 'placer' mining will undoubtedly be supplemented, sooner or later, by hydraulic mining on a large scale.

This report is well illustrated with views of the workings and with two maps of the Klondike mining district on a scale of two statute miles to one inch. A. H. F.

[1] Benches represent fragments of older valley-bottoms partially destroyed by the excavation of the present valleys.

II. — United States Geological Survey. Bulletin No. 268: Series C, Systematic Geology and Palæontology. Charles D. Walcott, Director. Miocene Foraminifera from the Monterey Shale of California: with a few Species from the Tejon Formation. By Rufus M. Bagg, jun. pp. 1–55, plates i–xi. 8vo. Washington, 1905.

THE Miocene Foraminifera described in the above Bulletin were collected by Professor J. C. Branner from the Monterey Shale near Asuncion Station, on the Southern Pacific Railway, in San Luis Obispo County, California.

The Monterey Shale is between 2,000 and 2,500 feet thick here, and forms one broad fold with many small faults. The shale contains layers that are more or less sandy and even flinty. An abundance of well-preserved Foraminifera occur in the softer parts of the shale, the bulk of which is made up of diatoms. The Monterey Shale rests in this region upon sandstones which are referred to the Chico Group; and it is overlain by beds regarded by the author as of Pliocene age, but by Dr. Fairbanks as Upper Miocene.

The result of a study of the fossils yielded an interesting fauna of sixty-six species, including a few varieties, and seventeen genera. The latter comprise *Bulimina*, *Bolivina*, *Lagena*, *Nodosaria*, *Cristellaria*, *Uvigerina*, *Sagrina*, *Globigerina*, *Orbulina*, *Pullenia*, *Discorbina*, *Truncatulina*, *Anomalina*, *Pulvinulina*, *Rotalia*, *Nonionina*, and *Polystomella*. Among these it will be noted that there are no arenaceous genera and species, nor warm water Miliolidæ; that there is only one member of the Nummulitic group, but a large number of rotaline types.

The majority of the forms represented are identical with such as are abundant in the North Atlantic Ocean at the present time, and the author considers that the conditions of oceanic temperature and depth at which the California beds were laid down are fairly represented in that sea. The fossils were probably deposited in waters the depth of which was less than 500 fathoms.

The fauna as a whole is remarkably similar to that of the older Pliocene beds of Monte Bartolomeo (Lake of Garda) described by Johann Egger in 1895, a fact already pointed out by Chapman (1900) in his report on the California Foraminifera (Proc. California Acad. Sci., ser. III, vol. i).

An interesting table is given showing the limits of depth of existing representatives of the fossil Foraminifera found in the Miocene of California. The depths vary from shoal water to upwards of 3,000 fathoms. The habitats of some species are limited to special localities; others have a worldwide oceanic distribution.

The table is followed by a list of the described species, systematically arranged, after which comes a bibliography in which many well-known works are enumerated; finally, the descriptions of the species, and a full index. A. H. F.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 7th, 1906.—Sir Archibald Geikie, D.C.L., Sc.D., Sec.R.S., President, in the Chair. The following communications were read:—

1. "On the occurrence of Limestone of the Lower Carboniferous Series in the Cannock Chase portion of the South Staffordshire Coalfield." By George Marmaduke Cockin, F.G.S.

Silurian limestone underlies the Coal-measures in the southern part of the South Staffordshire Coalfield, and a rock, probably similar, was found in a borehole at No. 2, Cannock Chase Colliery. A shaft was sunk some 30 years ago, about 5 miles north of the latter locality, at No. 1, Fair Oak, but was abandoned, as no workable coal-seam was found. Before the undertaking was abandoned, an exploration heading was driven for 44 yards in the direction of the dip, and from it heads along the strike for 150 yards. In the waste-heaps, which have remained undisturbed since 1875, a number of fossils belonging to the Lower Carboniferous Limestone have been found. A fault must be presumed to bring Carboniferous Limestone into such a position as to be reached by the headings. About $1\frac{1}{2}$ miles north-west of Fair Oak, rocks (determined by Mr. Walcot Gibson as Millstone Grit) were reached by a boring at 396 yards. An account of the strata pierced by the Fair Oak boring is appended.

2. "Liassic Dentaliidæ." By Linsdall Richardson, F.G.S.

Among the fossils collected in the cuttings on the new Honeybourne and Cheltenham Railway were many belonging to the family Dentaliidæ; and as the majority are new, the author has investigated the Liassic members of the family contained in his own collections and in those of numerous museums. The growth of the Scaphopod shell is effected by additions at the anterior end, while the posterior end suffers by wear and absorption. The members of this class are essentially marine, inhabiting deep water, and feeding principally on Foraminifera. The word *Dentalium* is used in the broad sense, and not in the restricted sense of a shell with strong longitudinal costæ. Eight new species are described, and eight species already known are discussed.

II.—March 21st, 1906. — Aubrey Strahan, M.A., F.R.S., Vice-President, in the Chair. The following communications were read:—

1. "The Chalk and Drift in Möen." By the Rev. Edwin Hill, M.A., F.G.S.

In 1899 Professor Bonney and the writer published a paper on Möen and Rügen: the present contribution contains results of further studies.

The problem of Möen is to account for portions of Drift, isolated, and seemingly included, in cliffs of Chalk. It has been generally assumed that these portions occupy dislocations, and that the dislocations were either simultaneous with, or subsequent to, the deposition of the Drift. But, in this paper, cases are described where Drift is seen to occupy cavities in dislocations, which had been water-worn, and consequently had been produced, before the advent of the Drift. The assumption hitherto generally made is, therefore, incorrect: the Chalk had been disturbed in pre-Glacial times. A probable assumption that there were pre-Glacial hills and cliffs similar to the present, with similar clefts and furrows in the cliffs, which were covered in Glacial times with a mantle of Drift now in course of removal by denudation, explains every variety of Drift inclusion. These varieties are described, and proofs are given of such an overlying mantle of Drift, even now over 100 feet thick on the flanks of the hills, and rising to their summits.

Differences from the Rügen phenomena are noted and explained. An apparent upward succession of Boulder-clay, shingle-beds, sand, and scattered boulders is discussed.

Slopes of uniform inclination which rise from the beach, often 60 feet and more, to the bases of the vertical cliffs, appear to be talus-slopes. In reality they are everywhere solid Chalk, with only a skin of débris: this suggests post-Glacial changes in sea-level.

Certain weathered-out hollows in cliff-faces indicate a way in which isolated portions of Drift might, when denudation had commenced, be long protected from destruction.

One instance of a Chalk boulder included in Drift emphasizes the general contrast, not likeness, between Möen and Cromer. The position of the Drift in Möen is similar to that of the Boulder-clays at Flamborough and along the Yorkshire coast. Had the Yorkshire Chalk been dislocated as that at Swanage or Lulworth, probably we should have in England similarities to Möen.

The author, with the Chairman's approval, read the following extract from a letter which he had received from Sir John Evans:—

"It is, I do not know how many, years ago that I visited the island of Möen, in company with the late Professor Steenstrup. The impression left on my mind by the abnormal contortions of the Drift was that they might, to a great extent, be due to the corrosion and erosion of the Chalk below, by the infiltration of water charged with carbonic acid. The surface of the Chalk in Hertfordshire is remarkably irregular, with deep indentations and numerous pinnacles. Within less than 100 yards of each other shafts may be sunk through Drift, and the Chalk in one shaft may be 30 or 40 feet below the surface, and in another only 10 or 15 feet. In a shaft about 6 feet in diameter, that I have lately had sunk near Berkhamsted Common, the surface of the Chalk on one side of the shaft is about 6 feet higher than it is on the other.

"On the Great Northern Railway, near Knebworth, there are pipes eroded to a great depth in the Chalk, which must have been formed since Pleistocene times, inasmuch as in the gravels let down in the pipes there are palæolithic implements. If I remember rightly, a similar pipe in the Valley of the Somme, cited by Prestwich, is 90 feet deep."

2. "On the Relations of the Chalk and Boulder-clay near Royston (Hertfordshire)." By Professor T. G. Bonney, Sc.D., LL.D., F.R.S., F.G.S.

On the uplands south of Royston, Mr. H. B. Woodward, F.R.S., has described three sections,[1] which in his opinion indicate that a great ice-sheet, as it advanced from the north, sheared off large masses of Chalk and mixed them up with its ground- or englacial moraine (the Chalky Boulder-clay).

The author points out that this interpretation rests on an hypothesis—namely, that the latter deposit is the direct product of land-ice—which, as it involves some serious difficulties, cannot yet be taken for granted. For instance, this clay in many parts of England contains chalk pebbles, more or less well-rounded, and often striated. But it is improbable that fragments of rock in either a ground- or an englacial moraine would be shaped into ordinary pebbles; and they would be brought into contact so seldom, and for so brief a time, that they would be but little scratched. But these chalk pebbles resemble those formed by water, either in a river-bed or (more probably) on a sea-beach. How, in the latter case, they could be striated Colonel H. W. Feilden showed twenty-eight years ago.

That ice is capable of shearing off and thrusting before it large masses of rock, is also an hypothesis, for which the author, after doing his best to study ice-work in the field, can find no valid evidence. He maintains that these sections do not suggest the above explanation. Passing over that "north of Reed" as unimportant, we come to the Pinner's Cross Pit. Here the Boulder-clay is not, strictly speaking, 'banked up' against the Chalk, as stated by Mr. Woodward, but occupies a hollow in the Chalk, as described by the late Mr. Penning. The Chalk has a fairly high dip, but there is little other sign of mechanical disturbance. In the pit south-west of Newsell's Park, a shear-plane can indeed be seen in one face, which, however, is explicable by ordinary faulting; and on the same face there are (or were) some small clayey patches. A few yards farther to the south-east, Boulder-clay appears above the floor of the pit, filling an arched cavity. This is, no doubt, a singular position, but there is nothing to show that the Chalk has been thrust over the Clay. The author suggests that, as in Möen and occasionally in Rügen, the Clay has been carried down from above into cavities already formed in the Chalk, and quotes a case from the latter island of a clay-filled cavity, which was connected with the surface and might have yielded a section like that in the above-named pit. Penning's diagram shows (probably nearly over this spot) Boulder-clay resting upon the Chalk. So the author maintains that, even if the fundamental hypotheses be true, they are not applicable to these sections.

3. "Brachiopod Homœomorphy: *Pygope*, *Antinomia*, *Pygites*." By S. S. Buckman, F.G.S.

[1] Quart. Journ. Geol. Soc., vol. lix (1903), p. 362.

This paper deals with the diphyoid Terebratulæ, of which so many species have borne the name *Terebratula diphya* (Colonna). It is pointed out that this name is pre-Linnean, and can only date from the time when it was revived by L. von Buch in 1834. Prior to that several names had been given to these shells. The first were *Terebratula cor* and *T. pileus* given by Bruguière in 1792 in the *Journal d'Histoire Naturelle*, his paper in which has been entirely overlooked by workers on these shells. Bruguière's names indicate a perforate and an imperforate species respectively. Consideration is then given to the synonymy of certain diphyoid species:—*T. triangulus*, Valenciennes, in Lamarck, which was actually founded on Bruguière's own figures of his *T. pileus*; *T. triquetra*, Parkinson, which includes two species, a perforate and an imperforate; and *T. antinomia*, Catullo, which covers various species. These and others all antedate *T. diphya*, L. von Buch.

It is pointed out that *Terebratula diphya* is not the type of the genus *Pygope*, as all text-books say; for Link, the author of the generic name, referred only to *T. antinomia*, Catullo. Reasons are given for taking as the type of *Pygope* one of the forms of *T. antinomia* which is considered to be the same species as *T. deltoidea*, Val. Then the latter generic name *Antinomia*, Catullo, is discussed. The genus was founded on five species, and one of them is now selected as the type—the genolectotype. This is *A. dilatata*, Catullo, supposed to be equivalent to *Terebratula antinomia*, Catullo, that is, to what is now selected to be the type of that species. In that case the species would bear the name *Antinomia antinomia* (Cat.). The two generic names *Pygope* and *Antinomia* are employed, because they are supposed to indicate two independent parallel genetic series, whose members differ in size and position of the perforation, and in characters of the lateral margin. But there is yet another series of diphyoids, typified by *Terebratula diphyoides*, d'Orb. It is pointed out that, although the species covered by the name *diphyoides* are very like *Pygope* as now used, yet they all differ in having particular characters in the preperforate stage—a dorsal ridge and a ventral sulcus. For this series de Haan's MS. name *Pygites* is used; and it is supposed that there are three genetic series of diphyoids which have developed independently, and that the remarkable perforate form, with its two lobes joined, has been evolved three times over. A genetic plate is given, figuring for comparison many of the species in the three series, showing their development from the glossothyridoid, to the bifidate, to the perforate (ordinary *T. diphya*) stage; and that then they finish by losing all trace of the perforation, the lobes completely coalescing (the imperforate stage), represented by *Terebratula pileus*, Brug.=*T. triangulus*, Val. in Lamarck.

Synonymies and short notices of the species in the three genera have been given. In compiling them there have been found two papers overlooked by Brachiopod bibliographers—one by E. Newman in the *Zoologist*, naming *T. Duvali*, and one by Catullo.